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Book Reviews

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Contents

In This Issue

"Thus it may appear, that there ought to be a great reciprocal influence between the mind and alimentary duct." David Hartley, **Observations on Man** (1749)

Despite a growing body of medical evidence linking diet with a number of diseases, many people have not changed their eating habits. Many reasons for this inaction have been cited, but little empirical evidence is available. Is the slow progress toward more healthy eating and lifestyles due to a lack of knowledge about nutrition and the nutrient content of foods, unawareness of diet-disease relationships, or perhaps simply an unwillingness to change? What does seem clear is that we need to go beyond traditional economic models of consumer demand for answers.

The fact remains that people buy foods that contain substances: some good, some harmful if eaten in excess. Economists have studied food choices for many years using classical demand theory as a guide. This theory and its extensions basically postulate that food choices are determined by prices, income, and the socio-economic characteristics of individuals. Clearly, other, more subjective influences, such as knowledge and attitudes, are at work—but usually ignored. Society, in turn, will bear enormous opportunity costs if we do not break the chains that bind us to traditional types of analyses.

The lead article in this issue takes a step forward by recognizing that awareness of diet-disease relationships may help explain a woman's fat intake. The authors, Dan Putler and Betsy Frazao, first estimate a model designed to examine how the probability of diet-health awareness varies with the demographic profile of the surveyed women. They then use this probability along with other variables to construct a model of fat intake. Despite systematic changes in food consumption associated with higher awareness probabilities, the more-aware women showed no greater reduction in fat intake than others. The authors postulate that difficulties in making effective food substitutions may be due to insufficient knowledge about the relative fat content of different foods. This research represents a first step on a long journey.

Larry Salathe's article, "The Implications of Offsetting Adjustments in Government Purchase Prices for Butter and Nonfat Dry Milk," develops a model that could be used to improve the operation of USDA's dairy price support program. Since 1988, Commodity Credit Corporation purchases of milkfat have greatly exceeded purchases of nonfat milk solids. USDA has responded by reducing the purchase price of butter and raising the purchase price of nonfat dry milk twice in 1990 and twice in 1992. Salathe develops a model that derives offsetting adjustments in butter and nonfat dry milk prices that would balance CCC purchases of these two commodities on a milk equivalent basis and minimize CCC purchase costs. Applying the model to the 1991 market situation suggests that CCC's purchase price of butter would have had to be reduced 35-40 cents per pound before purchases would have been equal on a milk equivalent basis. Salathe concludes that this balancing would have reduced CCC dairy purchases by about $125 million in 1991.

Lloyd Teigen's article, "Cost, Supply, and Farm Structure: A Pedagogical Note," reminds us of the importance of truly understanding the linkage between basic microeconomic theory of the firm and the real world. Teigen argues that textbook cost curves for "representative" firms are drawn too close together and thus fail to illustrate the wide diversity of technologies that often exist among firms. He goes on to show just how powerful simple microeconomic principles can be in understanding industry structure and trends. Using the dairy industry as an example, he applies the quadratic production function and derives all the related marginal and average cost, supply, and input demand functions. Explicit aggregation from firm to market shows that properly specified aggregate functions depend on the distribution and number of firms.

In the first of two book reviews, Olan Forker says that *Market Demand for Dairy Products,* edited by Johnson, Stonehouse, and Hassan, contains a "wealth of information" on demand analysis for dairy products, including alternative theories and methods of analysis, market demand studies for various dairy products, and the impact of generic advertising. Forker recommends the book as a reference for academicians, researchers, and students, as well as dairy industry participants.

Fred Rupple has mixed feelings about Luther Tweeten's new book, *Agricultural Trade: Principles and Policies.* Rupple reports that the text is probably too advanced for some of its intended audiences: in particular, the general public and

even some upper-division undergraduate courses. While some chapters would be useful to these groups, he feels that most chapters and topics are much too advanced in their presentation style and content for these two groups. His assessment is that the text is geared to professional economists and agricultural economists working on trade issues. He feels the major contribution of this book is in the trade and agricultural policy arena rather than trade theory, a big plus for us working in the real world!

James Blaylock
David Smallwood

Consumer Awareness of Diet-Disease Relationships and Dietary Behavior: The Case of Dietary Fat

D.S. Putler and E. Frazao

Abstract. *We use FDA surveys on awareness of diet-disease relationships to estimate a probability model of awareness. We apply the model to respondents of USDA's 1985-88 food consumption surveys to estimate a predicted probability of awareness, an explanatory variable in the multivariate analysis of fat intake. Despite systematic changes in food behavior associated with diet-disease awareness, women with higher awareness probabilities showed no greater reduction in fat intake than others. Difficulties in making effective food substitutions may be due to insufficient knowledge about the relative fat content of different food groups. More research is needed to understand the complex link between diet-disease awareness and dietary practices.*

Keywords. *Awareness of diet-disease relationships, fat intake, dietary practices.*

Since the 1970's a consensus has emerged in the American public health community that changes in diet and other personal habits, such as exercise and smoking, can reduce the risk of such chronic diseases as cancer, heart disease, stroke, and hypertension (National Research Council, 1989 and 1991; U.S. Department of Health and Human Services, 1988). As a result, nutrition information and education activities in the United States have shifted from efforts to eliminate nutrient deficiency diseases, such as rickets and pellagra, to efforts to reduce chronic disease risks associated with overconsumption of fat, saturated fat, cholesterol, and sodium, and inadequate consumption of dietary fiber.

The effectiveness of informing the public as a means of altering dietary patterns has been judged by examining changes in public awareness of diet-disease relationships and trends in per capita food consumption of specific commodities (like beef, whole milk, and fresh vegetables) (Levy and Heimbach, 1989; National Research Council, 1989 and 1991; Putnam and Allshouse, 1991; Schucker and others, 1987; Shekelle and Liu, 1978).

This article examines whether individuals more likely to be aware of a diet-disease relationship are more likely to alter their food choices to achieve dietary objectives. Specifically, we examine how women more likely to be aware of the relationship between dietary fat consumption and the risks of contracting coronary heart disease and certain types of cancer alter their food consumption behavior. And, if altered, do these changes in food consumption lower their intake of fat, saturated fat, and cholesterol, relative to other women who are less likely to be aware of the diet-disease relationship.

Between 1977 and 1985, awareness of the link between fat intake and coronary heart disease increased on the order of 200-250 percent (Putler and Frazao, 1991). Although all segments of society experienced increases in awareness during this time period, the rate of increase varied greatly for different demographic groups. Shekelle and Liu (1978) indicate that there was little, if any, variation in the level of awareness across different demographic groups in 1977. However, Schucker and others (1987) report that by the mid-1980's less educated, nonwhite, and low-income individuals had substantially lower awareness levels compared with other groups in society.

Comparing the dietary changes of groups with the greatest increases in awareness with those experienced by other groups indicates the effect of awareness on dietary behavior. Harris and Welsh (1989) and Putler and Frazao (1991) relate proxies for diet-health awareness to a total diet measure, the percentage of calories obtained from fat. The findings of both studies suggest that women with higher awareness levels have made the greatest changes in their food choice behavior.[1] However, changes in total fat intake levels were essentially uniform across different demographic groups. Consequently, groups of women with higher levels of awareness were no more successful at lowering

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[1]Putler and Frazao (1991) explicitly argue that differences in dietary behavior across demographic groups can be used to indicate the effects of increased levels of diet-disease awareness. However, Harris and Welsh (1989) do not make this argument.

total fat intake than groups of women with lower awareness levels.[2]

At the time of this study, no data set was available that measured whether an individual was aware of specific diet-disease relationships and simultaneously measured his or her actual food consumption behavior.[3] However, several surveys of either diet-disease awareness or dietary behavior have been conducted since the mid-1980's. The U.S. Food and Drug Administration (FDA) conducts the Health and Diet Surveys (HDS) to track the public's awareness and knowledge of diet and health issues. The U.S. Department of Agriculture's Human Nutrition Information Service conducts surveys of individual food consumption and nutrient intake. The food consumption and nutrient intake data used in this study are from the 1985 and 1986 Continuing Survey of Food Intakes by Individuals (CSFII) and the 1987-88 Nationwide Food Consumption Survey (NFCS).

We combine awareness and food consumption data by utilizing the strong demographic patterns that exist in the awareness of the link between fat intake and chronic disease. Specifically, we use the FDA-HDS data to estimate a probability model of awareness, using survey participants' demographic characteristics as explanatory variables. The fitted probability model is then coupled with the demographic characteristics of individual respondents in the food intake surveys to predict a probability of awareness for each respondent. The more likely it is that an individual consumer is aware of the link between fat intake and chronic disease, the more likely that consumer is to alter food consumption behavior in an attempt to lower intake of fat, saturated fat, and cholesterol. Although the fitted probability of awareness is an indirect measure, it is closely and directly tied to actual awareness. As a result, it should be strongly indicative of the effects of diet-disease awareness on food consumption behavior.

[2]Harris and Welsh's (1989) study is based on differences in dietary behavior across different income groups. Putler and Frazao's (1991) study controls for a number of additional factors using multivariate statistical analysis. Another study that indirectly measures the effects of awareness on dietary behavior is Ippolito and Mathios (1989). The study examined the effect on fiber cereal consumption of Kellogg's advertising and labeling of All-Bran and Bran Flakes to convey the reduced cancer risk benefits associated with higher levels of fiber consumption.

[3]A new group of surveys, the 1989, 1990, and 1991 Continuing Survey of Food Intakes by Individuals, conducted by the Human Nutrition Information Service (HNIS) of the U.S. Department of Agriculture, measures both diet-disease awareness and food consumption data for the same individual. However, the first of these surveys (the 1989 survey) did not become available until late 1992.

Demographic Differences in Diet-Disease Awareness

The HDS is a multi-instrument random digit dialing telephone survey of 3,200-4,000 individuals over the age of 18 residing in the 48 contiguous States. The survey has been conducted roughly once every 2 years since 1982. The survey tracks consumer awareness of the link between the consumption of certain nutrients and chronic diseases, and attempts to assess usage and understanding of food labeling information, general nutrition knowledge and understanding, and self-reported dieting.

Since 1983-84, the HDS has included a pair of unaided recall questions to elicit whether a consumer is aware of the link between dietary fat consumption and chronic disease.[4] The first question is:

> "Another thing found in many foods is *fat*. Have you heard about any health problems that might be related to how much *fat* people consume?"

Respondents who answer "yes" to this question are then asked,

> "What health problems might be related to how much fat people consume? Are there any other health problems that might be related to how much fat people consume?"

The second part of this question is repeated until the respondent can no longer name additional disease conditions.[5]

In our analysis, a respondent was considered as being aware of health problems associated with high fat intake if he or she responded with coronary heart disease, vascular diseases, or cancer. Nearly all respondents who indicate that fat consumption was linked to health problems responded with at least one of these diseases.

Awareness Trends

Figure 1 shows the percentage of the usable sample that reported that fat consumption was linked to coronary or vascular diseases or cancer. Awareness is at a relatively high level, about 75 percent, with little change in overall awareness between 1986 and 1988. This suggests that diet-disease awareness had peaked by 1986.

[4]The 1983-84 HDS began data collection in December of 1983 and concluded the collection in January of 1984.

[5]The typical respondent can name one or two different diseases.

Figure 1
Proportion of sample aware of diet-disease relationship

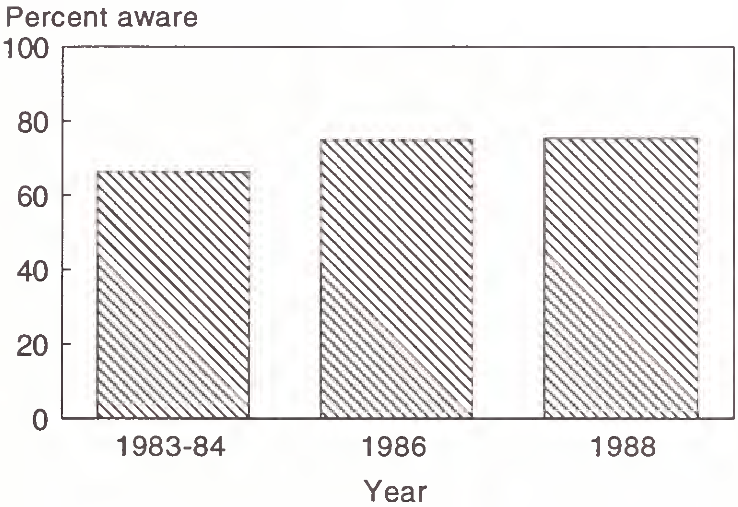
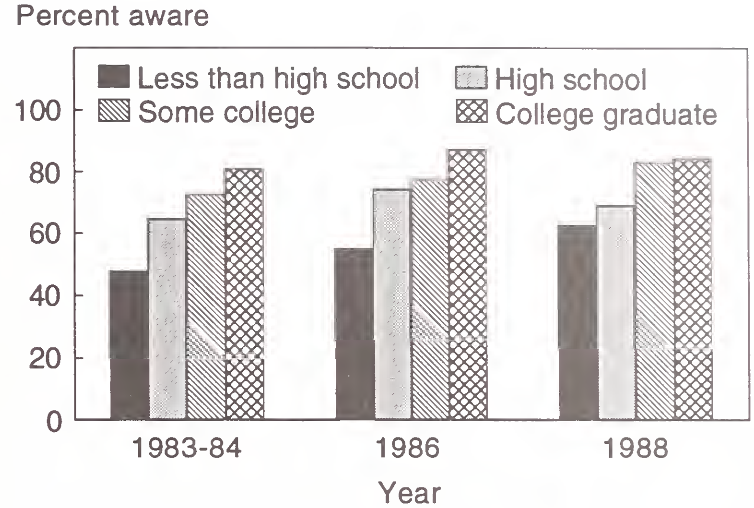


Figure 2
Differences in awareness, by education level



Despite the high awareness levels of the link between fat intake and chronic disease, there are strong differences in awareness levels across demographic groups. For example, individuals with higher education levels are more likely to be aware of the link between fat intake and chronic diseases than are individuals with lower levels of formal education (fig. 2).

Measuring Awareness

Demographic characteristics are hypothesized to influence the probability that an individual is aware of the link between fat intake and chronic disease. Due to the discrete nature of our awareness measure—an individual is either aware or not aware—a logit probability model is chosen for estimation purposes.[6]

The variables used in the logit analysis are those demographic factors believed to influence differences in both access to diet-disease information and concern for personal health. Only demographic factors that are measured in both the HDS and the individual food intake surveys are used. Demographic factors relate to age, race, sex[7], years of schooling, income level, and smoking status (yes or no) for each respondent (table 1).

Previous surveys (Food Marketing Institute, 1990; Gallup, 1990) indicate that men are typically less interested in diet and health issues than are women. As a result, they are probably less likely to seek out and pay attention to information on diet-disease relationships, and, consequently, are less likely to be aware of these relationships.

Racial differences were expected to influence diet-disease awareness because of differences in media habits among different racial groups. For example, blacks have lower newspaper and magazine readership rates than do non-Hispanic whites (U.S. Department of Health and Human Services, 1992). Since newspapers and magazines are the primary way that diet-disease information has been conveyed to consumers (Gallup, 1990), it is likely that blacks have lower awareness levels. For similar reasons, coupled with lower levels of English language fluency, we anticipated that both Hispanics and the "other" race category, primarily Asians and Native Americans, would have lower levels of diet-disease awareness compared with non-Hispanic whites.

Table 1—Explanatory variables and expected signs in the logit analysis of awareness

Variable	Expected sign
Age	+
Age-squared	–
Male	–
Non-Hispanic black	–
Hispanic	–
Non-Hispanic other race	–
Some high school	+
High school graduate	+
Some college	+
College graduate	+
Post graduate	+
Income residual	+
Income not reported	–
Smoker	–

[6]Maddala (1983) shows that logit and probit models yield very similar estimation results. The logit model is used in this analysis because it is computationally less burdensome when used to predict probabilities.

[7]Although we were interested in modeling awareness among women, data on men were included to increase the sample size.

Some of the differences in readership rates may be due to differences in education levels. For example, the number of media items read increases with years of formal education (U.S. Department of Health and Human Services, 1992). As a result, it is hypothesized that access to diet-disease information will be higher among individuals with education above the elementary school level; moreover, the size of the effects increases with higher levels of formal education.

Given the almost universal awareness of the adverse health effects of smoking, one's choice to smoke provides an indication of how likely health concerns are to alter one's behavior. A smoker is likely to place a lower value on their own health than a demographically similar nonsmoker, and, consequently, is less likely to seek out or pay attention to information related to health, including information on diet-disease relationships.

Age and the square of age are included since it seems likely that beyond the age of 18, the probability of awareness would first rise, reach a peak, and then begin to decline. The effects of income on the probability of awareness are captured using two variables. In each year, roughly 15 percent of the survey respondents did not answer the question on their household income level. In addition to greatly reducing the sample size, omitting these respondents from the survey increases the probability that the remaining sample suffers from self-selection bias. In particular, it may be that individuals who refused to answer the income question may be less interested or less aware of the topics covered in the survey, and, therefore, less likely to be aware of diet-disease relationships. As a result, nonrespondents to the household income question were kept in the estimation sample, and an indicator variable, income not reported, was included to control for their presence.[8]

To capture the effects of income that are not captured by other demographic factors, residuals from estimated income equations were included in the final logit model. These residuals were obtained from regression equations in which income was regressed on the remaining demographic factors. The income residual is a proxy for a set of individual skills that are positively related to both household income level and the probability of diet-disease awareness, but that are not directly related to other included demographic factors.

[8]Nonresponse rates to the household income question in the HDS were similar to the non-response rates for the respondents to the individual food intake surveys.

Separate logit models were estimated for each of the three HDS surveys with similar results. Thus, the 1986 and 1988 samples were combined in the final logit model to increase the reliability of the estimated coefficients (table 2).

Results

The model correctly classifies 76.4 percent of the respondents, and the likelihood-ratio test of the hypothesis that all model coefficients except the intercept can be set equal to zero is rejected with a very high level of confidence ($\chi^2_{(14\ df)} = 170.97$, $p < 0.00001$). The signs of all the explanatory variables (excluding the intercept) are as anticipated, and significant. The coefficients on the education variables increase as years of formal schooling increase. The coefficients on age and the square of age indicate that the probability of awareness peaks at about age 50 and then begins to decline. Finally, results suggest little difference in the probability of awareness between nonsmokers and smokers and between non-Hispanic whites and individuals in the "other" race category.

The probability that an individual is aware of the link between dietary fats and chronic disease varies significantly with age, sex, education level, race, and income. Furthermore, the probability that an individual is aware of this information can be predicted with a reasonably high degree of accuracy based on their demographic profile. Thus,

Table 2—Estimation results for the diet-disease awareness model based on the 1986 and 1988 FDA-HDS data

Variable	Coefficient	Asymptotic T-Ratio
Age	0.1095	5.586*
Age-squared	–.0010	–5.206*
Male	–.4899	–3.928*
Non-Hispanic black	–.9245	–4.898*
Hispanic	–.4779	–1.601
Non-Hispanic other race	–.1867	– .641
Some high school	.4321	1.528
High school graduate	.8502	3.325*
Some college	1.4144	5.167*
College graduate	1.6440	5.570*
Post graduate	1.8526	5.259*
Income residual	.0132	2.949**
Income not reported	–.3012	–1.785***
Smoker	–.1600	–1.193
Intercept	–1.9676	–3.875*
Percent correct prediction	76.4%	
Log of the likelihood function	–855.97	
χ^2, 15 degrees of freedom	170.97*	
N	1692	

*$p < 0.001$
**$p < 0.01$
***$p < 0.10$

the demographic profiles of the respondents to the food intake surveys may be used to predict an individual's probability of diet-disease awareness, and, in turn, this estimated probability may be used as an explanatory variable in analyses of food consumption behavior.

Diet-Disease Awareness and Food Group Consumption Behavior

The 1985 and 1986 CSFII and the 1987-88 NFCS provide detailed information on an individual's food consumption and nutrient intake based on the foods he or she consumed over a 24-hour period. All the surveys are based on independent samples drawn from the 48 contiguous States. In each survey, demographic information on household members is collected through a personal interview (U.S. Department of Agriculture, 1985 and 1991). Although the intent and many practical aspects of the two types of surveys are nearly identical, there are some important methodological differences between the CSFII and the NFCS.

The core sample for both the 1985 and 1986 CSFII are women aged 19-50 and their children aged 1-5.[9] The surveys were initiated in April of each year, and consisted of six waves over a 12-month period. Food consumption data were collected for each respondent using a 24-hour dietary recall in each wave.[10] The first day of food consumption data (the first wave) was collected using a personal interview. Subsequent days of data were collected by telephone at approximately 2-month intervals. Individuals in households without telephones were contacted in person (U.S. Department of Agriculture, 1985).

The sample for the 1987-88 NFCS includes all individuals, regardless of sex or age. Food consumption and nutrient intake data were collected from each respondent over 3 successive days. The first day of data was obtained using a 24-hour dietary recall administered through a personal interview. The subsequent 2 days of data were obtained using a food intake diary completed by the respondent (U.S. Department of Agriculture, 1991).

The 1987-88 NFCS had a sample response rate of approximately 35 percent. As a result of this low response and the potential for bias, the Life Sciences Research Office (Life Sciences Research Office, 1991) recommended that the 1987-88 NFCS be used only in conjunction with other data, such as the 1985 and 1986 CSFII.[11] Thus, the four samples (1985 CSFII, 1986 CSFII, 1987 NFCS, and 1988 NFCS) are analyzed separately and are not pooled in this report.

The sample for this study was carefully selected to maximize comparability between the data sources and minimize the methodological differences between the surveys. The following criteria were used in determining the final sample: (1) individuals in the 1987-88 NFCS had to be women aged 19-50 for comparison with the 1985 and 1986 CSFII; (2) only food consumption data from the 24-hour dietary recall of the 1987-88 NFCS and the first wave of the 1985 and 1986 CSFII are used since both are based on the same collection methodology; (3) because the first wave of data for the 1985 and 1986 CSFII was collected in April-June, only data for April-August in each year of the 1987-88 NFCS are used in an effort to reduce the effects of seasonality on food consumption patterns; [12] (4) since the 1987-88 NFCS collected education levels for only the male and female household heads, the 1985 and 1986 CSFII sample included only women from households where the female head of household is also a respondent;[13] and (5) only women with complete data on food consumption and from households that reported the demographic information necessary to predict the probability of diet-disease awareness are included. Based on these five criteria, the sample sizes are 1,346 women for 1985, 1,336 women for 1986, 448 women for 1987, and 705 women for 1988.

Food Groups

The number of distinct food items eaten by American consumers on any given day is incredibly diverse. The women in each sample ate thousands

[9]In addition to this core sample, other population subgroups are surveyed. The 1985 CSFII also contained a sample of under 1,000 men aged 19-50. Men were not surveyed in the 1986 CSFII.

[10]In a 24-hour dietary recall, an interviewer elicits from each individual the kinds and amounts of each food eaten over the last 24 hours. In the 1985 and 1986 CSFII and the 1987-88 NFCS, interviewers used a food instruction booklet to help respondents adequately describe foods eaten. In addition, interviewers used standard household measuring cups and spoons and a ruler to help respondents estimate quantities of foods and beverages consumed.

[11]It is generally believed that none of these past surveys suffers from nonresponse bias.

[12]The 1987-88 NFCS sample included women interviewed from June to August in order to ensure an acceptable number of observations.

[13]In the 1985 and 1986 CSFII, the education level of the women included in the sample was collected from each household. Consequently, the education level of the female household head is available only for households where she is a respondent. Since the education level of only the female household head was available in the 1987-88 NFCS, the fitted probability of awareness actually pertains to the female head of household and not necessarily the respondent. However, approximately 90 percent of the sample are female household heads.

of different food items, which are aggregated into a manageable number of groups for this analysis. Forming food groups is always somewhat arbitrary since there is no single correct way of grouping different food items. However, a great deal of thought was given to how and when foods are used in an effort to keep similarly used food items within the same grouping. In addition, some foods that have been placed into a single food group in past studies, such as red meats, poultry, and fish (Harris and Welsh, 1989; U.S. Department of Agriculture, 1985 and 1987), are disaggregated into smaller groups due to likely differences in consumer perceptions about different items within the historically used food group. All food items mentioned in the dietary recall data are aggregated into 11 exhaustive food groups (see appendix).

Table 3—Weighted average distribution of total fat intake among the 11 food groups

Food Group	Percent of total fat intake
Red meats	24.41
Dairy products	16.32
Food fats, dressings, and sauces	12.28
Poultry, fish, and seafood	8.89
Baked and frozen desserts	8.43
Legumes and starches	7.79
Cereals, breads, and pastries	6.82
Salty snacks, nuts, and peanut butter	5.73
Eggs and egg dishes	4.06
Fruits and vegetables	3.50
Soups, beverages, and sweeteners	1.78

Source: Combined sample of the 1985 and 1986 CSFII and the 1987-88 NFCS (n=3,835).

Food mixtures, such as sandwiches and casseroles, are not broken down into their individual ingredients, but are assigned to a food group based on the primary ingredient. Thus, a hamburger with a bun is included in the "red meats" food group, while spaghetti with meat sauce is included in the "legumes and starches" food groups since spaghetti is the mixture's main ingredient. The primary reason for assigning food mixtures to a single food category based on its primary ingredient, rather than breaking the mixture up into its constituent ingredients, is that individuals frequently make choices over different food mixtures, not over individual ingredients. For example, an individual chooses to eat a slice of pizza, not the cheese, flour, tomato sauce, and other ingredients that make up the slice of pizza. In studying food consumption behavior, we believe it is more appropriate to analyze food choices in the form that the foods are eaten.

Sources of Dietary Fat

Table 3 gives the average share of total fat provided by each of the 11 food groups based on the combined samples of the 1985 and 1986 CSFII, and the 1987 and 1988 portions of the 1987-88 NFCS. Red meats, dairy products, and food fats, dressings, and sauces are the three main sources of dietary fat, accounting for over half of all fat intake, on average. The next four food groups (poultry, fish, and seafood; baked and frozen desserts; legumes and starches; and cereals, breads, and pastries) together contribute an additional 30 percent to total fat intake. Salty snacks, nuts, and peanut butter; eggs and egg dishes; fruits and vegetables; and soups, beverages, and sweeteners contribute the remaining 20 percent of average total fat intake.

The share of total fat from the five food groups principally responsible for providing dietary fat varies across quartiles of diet-disease awareness probabilities (fig. 3-7). Increases in the probability of diet-disease awareness are strongly associated with a lower share of fat from red meats (fig. 3), but tend to be associated with higher shares of fat from food fats, dressings, and sauces (fig. 5), and baked and frozen desserts (fig. 7). There is no apparent relationship between the probability of diet-disease awareness and the share of total fat from dairy products (fig. 4) or from poultry, fish, and seafood (fig. 6).

To confirm that the effect of the estimated probability of awareness on diet changes is really due to diet-disease awareness and not due to some underlying demographic characteristic, figure 3 for red meats includes information from the 1977-78 NFCS (U.S. Department of Agriculture, 1983)[14], a time period when diet-disease awareness levels were low (Shekelle and Liu, 1978). Thus, a fitted probability of awareness would not be indicative of differences in diet-disease awareness levels in 1977, but an indicator of underlying demographic differences. Figure 3 reveals strong and systematic differences in the share of fat from red meats across awareness quartiles for 1985-1988, but does not show any appreciable differences in 1977. Consequently, it appears that the estimated probability of awareness is capturing the effects of diet-disease awareness, and not underlying demographic differences. Moreover, figure 3 suggests that increases in diet-disease awareness have had a measurable impact on women's food choices.

[14]Red meats are chosen because this food group is the primary dietary source of fat and because it shows the greatest differences across awareness quartiles.

Figure 3
Share of fat from red meats, sausages, and cold cuts, by awareness level

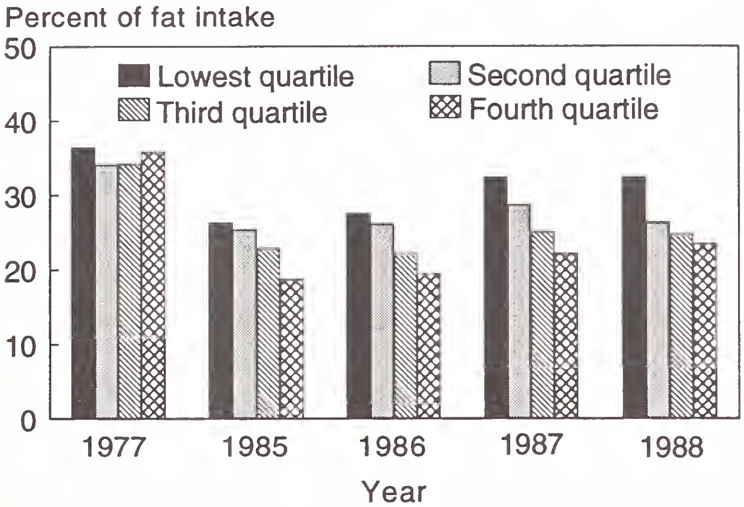


Figure 4
Share of fat from dairy products, by awareness level

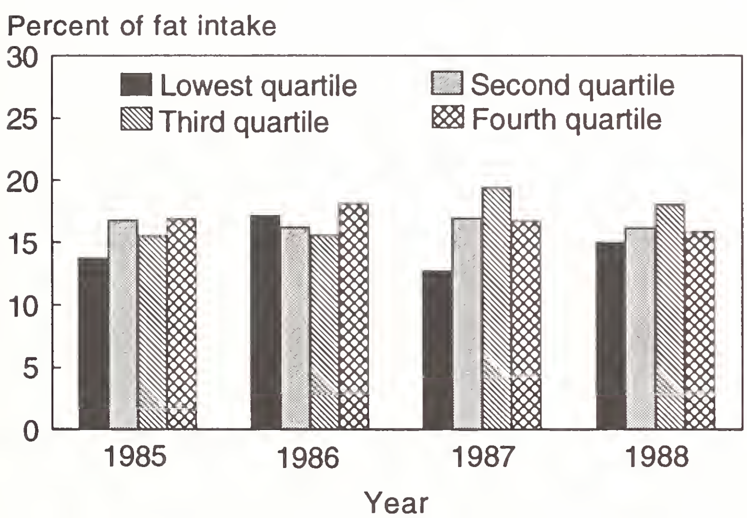


Figure 5
Share of fat from food fats, dressings, and sauces, by awareness level

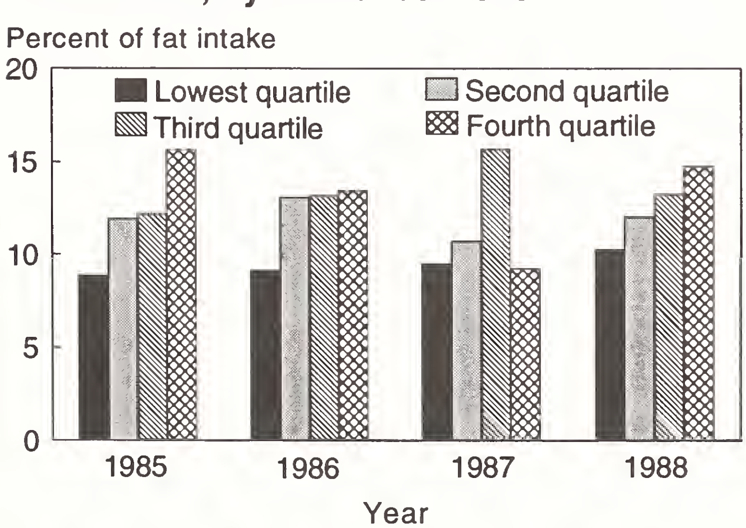


Figure 6
Share of fat from poultry, fish, and seafood, by awareness level

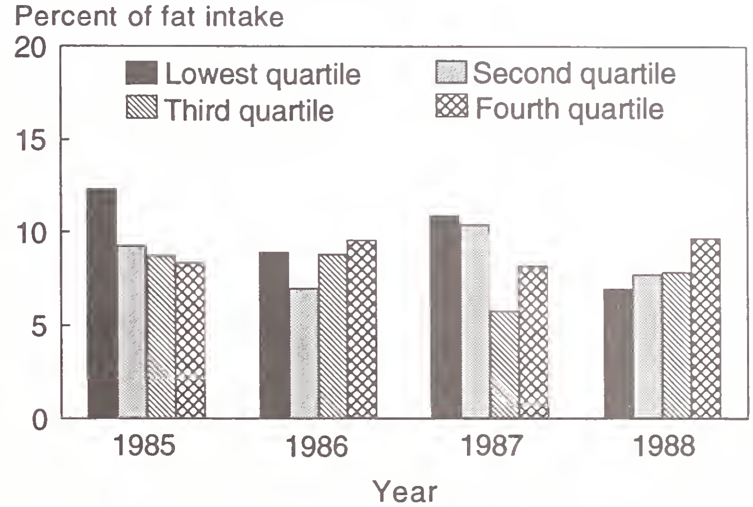
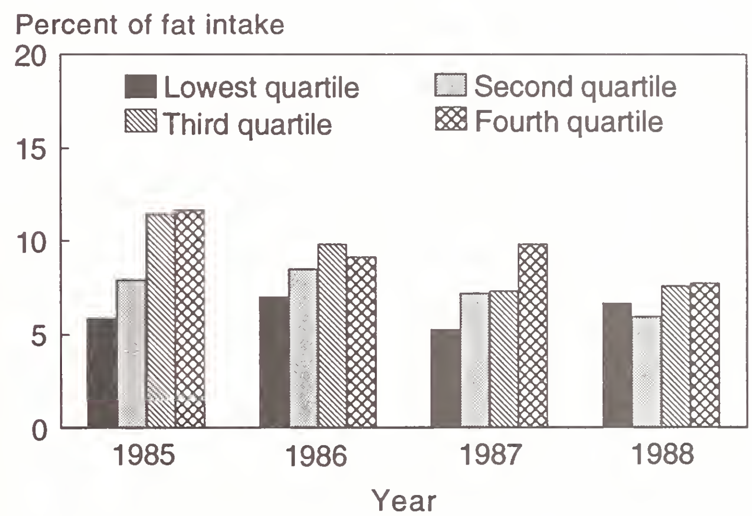


Figure 7
Share of fat from frozen and baked desserts, by awareness level



Multivariate Statistical Analyses of the Food Sources of Dietary Fat

Survey data revealed that a sizable proportion of women in each sample did not consume any items from a particular group. As a result, a limited dependent variable estimation procedure is used instead of classical least-squares regression. Three different estimation procedures are used: one-limit tobit, probit, and truncated normal maximum likelihood estimation (Maddala, 1983).[15] We choose to use the three different procedures since each addresses a different question. Probit provides an analysis of the probability that an individual consumed any items from a given food group. Truncated normal maximum likelihood estimation

[15]Together, the probit and truncated normal maximum likelihood constitute one variant of the "Cragg" model (Cragg, 1971).

(MLE) analyzes the importance of a food group as a source of dietary fat in an individual's diet, given that the individual ate at least one item from the food group. The one-limit tobit uses a single equation to account for whether an individual consumed an item from a food group and the share of fat attributed to that food group.

Although the one-limit tobit estimator has the advantage of addressing both questions at once, it assumes that a given explanatory variable has exactly the same influence in determining whether any item from a food group is consumed as it does on the relative importance of the food group in providing dietary fat if it is consumed.[16] The combination of the probit and the truncated normal MLE allows an explanatory variable to have a different effect on the choice of whether to consume from a food group than it does on the importance of the food group in providing dietary fat, given that items from the group are consumed. However, the ability to allow the effect of an explanatory variable to vary across the two measures comes at the cost of assuming that the choice of whether to consume items from a food group is independent of the importance of that group in providing dietary fat given that it is consumed.[17]

Past research on food consumption indicates that demographic and other characteristics have a strong influence on behavior (Cox and Wohlgenant, 1986; Haines, Guilkey, and Popkin, 1988; Lee and Phillips, 1971; Popkin, Guilkey, and Haines, 1989; Putler and Frazao, 1991; West and Price, 1976). These studies demonstrate the importance of biological factors (such as a woman's age, weight, and whether she is pregnant or lactating), special dietary behavior, race and ethnicity, residence (urban/suburban/rural and region of the country), household structure, financial resource level, employment patterns (is the female head employed), reported day (in the week) of intake data in explaining differences in food consumption patterns (table 4). Income is expressed as a percentage of the time-specific poverty level to partially control for both inflation and household size.[18] The public assistance variable indicates whether a member of the household is currently enrolled in the Supplemental Feeding Program for Women, Infants, and Children (WIC) or receives food stamps. Finally, the weekend variable indicates whether the 24-hour intake data from a respondent included a Saturday or Sunday.

Because of the large number of estimated equations needed to analyze food group choices and dietary sources of fat, the complete set of estimation results are not presented here.[19] Instead, tables 5 and 6 provide summaries of the results.

Table 5 contains the number of times each of the explanatory variables is found to have a significant effect on the consumption of a food group for each of the estimation procedures. A variable is defined to have a significant effect on a food group if it is statistically significant in at least two of the four samples with at least one of the significant coefficients falling in either the 1985 or 1986 sample.[20] In addition, a variable has to have the same sign for a given estimation procedure and food group across the four different samples. The same definition of significant effects is used in table 6.

Table 5 results tend to confirm Haines, Guilkey, and Popkin's (1988) finding that the tobit estimation results tend to be more consistent with the probit results than with the truncated normal MLE results. This suggests that the tobit models are primarily reflecting the decision to consume from a particular food group. The fitted diet-disease probability appears to be one of the primary factors determining systematic differences in dietary behavior across individuals since it is significant more often than any other factor. Moreover, diet-disease awareness has a relatively greater influence on the choice of whether to consume from a particular food group than it does on the importance of the food group in providing dietary fat, given that some item from the group is

[16]In a study of the effects of demographic factors on food consumption, Haines, Guilkey, and Popkin (1988) find that the tobit results are much more consistent with the probit results than with the truncated regression results. As a result, they argue that the tobit procedure is primarily picking up the effects of the choice of whether or not to consume a particular food.

[17]A generalized tobit procedure, also known as a type 2 tobit (Amemiya, 1985), has been developed that allows the explanatory variables to have differential effects on the two measures, and also accounts for the potential codependence between the measures. It does this by assuming that the errors of the two measures are jointly and normally distributed. Using this assumption, model parameters are estimated using maximum likelihood for the joint distribution. However, the procedure has extremely poor convergence properties, and is computationally intensive since it requires double numerical integration over the parameters of a joint likelihood function. The use of the generalized tobit was deemed infeasible for this study since it would require the use of the procedure in 44 separate instances (4 samples by 11 food groups).

[18]In a given year, the household income level needed to meet the poverty level varies with the size of the household.

[19]For this portion of the study, 132 different equations were estimated (11 food groups by 4 samples by 3 estimation procedures). A complete set of results can be obtained from the authors upon request.

[20]The requirement that a variable needs to be statistically significant in 1985 or 1986 is to lessen the possible effects of non-response bias associated with the 1987-88 NFCS.

Table 4—Explanatory Variables and Sample Means

Variable	1985 (n=1,346)	1986 (n=1,336)	1987 (n=448)	1988 (n=705)
Awareness of the female head	0.77	0.78	0.76	0.78
Percentage of poverty	2.74	2.98	3.13	3.18
Public assistance (0,1)	.12	.09	.14	.11
Non-Hispanic black (0,1)	.08	.06	.13	.11
Hispanic (0,1)	.05	.04	.06	.06
Non-Hispanic other race (0,1)	.03	.03	.04	.02
Non-Hispanic white (Omitted)	.84	.87	.77	.81
Age	33.49	34.01	34.08	33.49
Weight	140.38	143.96	143.30	142.99
Pregnant/lactating (0,1)	.04	.03	.06	.05
On special diet (0,1)	.12	.14	.08	.10
Vegetarian (0,1)	.03	.02	.02	.03
Male head present (0,1)	.73	.75	.75	.76
Children present (0,1)	.69	.70	.65	.65
Female head employed (0,1)	.61	.61	.62	.68
Urban (0,1)	.27	.25	.27	.20
Suburban (0,1)	.50	.51	.42	.55
Rural (Omitted)	.23	.24	.31	.25
North-Central (0,1)	.28	.27	.21	.27
South (0,1)	.33	.32	.43	.35
West (0,1)	.18	.21	.20	.18
North East (Omitted)	.21	.20	.16	.20

Source: 1985 and 1986 CSFII and 1987-88 NFCS

Table 5—Variables that significantly influence food choices and dietary sources of fat

	Number of times a variable has a significant effect*			
Variable	Tobit	Probit	Truncated normal MLE	Total
Awareness of the female head	5	6	1	12
Percentage of poverty	1	1	0	2
Public assistance	0	0	1	1
Non-Hispanic black	3	5	2	10
Hispanic	1	1	0	2
Non-Hispanic other race	5	2	0	7
Age	2	1	1	4
Weight	0	0	0	0
Pregnant/lactating	1	5	1	7
On special diet	3	4	1	8
Vegetarian	2	1	2	5
Male head present	2	0	0	2
Children present	0	0	0	0
Female head employed	0	1	0	1
Urban	0	0	0	0
Suburban	0	0	0	0
North-Central	1	1	1	3
South	3	1	1	5
West	0	0	0	0
Weekend	1	1	1	3

*The maximum number of times a variable could be significant for each estimation procedure is 11.

consumed. Finally, several factors other than diet-disease awareness have a strong influence on food choice behavior. In particular, race and ethnicity, biological factors (age and whether a women is pregnant or lactating), special dietary practices (vegetarianism or whether a woman is on a special diet), and the region of the country in which a woman resides all have significant effects on food choices and the relative importance of different food groups in providing dietary fat.

To gain an understanding of what effects diet-disease awareness has on food choices, table 6 contains a summary of the significance and signs of the fitted probability of awareness for each of the 11 food groups. As the probability of diet-

Table 6—The effect of diet-disease awareness on specific food choices

Food group	Tobit	Probit	Truncated normal MLE
Red meat	–	–	NS
Dairy product	NS	NS	NS
Food fats, dressings, and sauces	NS	+	NS
Poultry and seafood	+	+	NS
Baked and frozen desserts	+	+	NS
Legumes and starches	NS	NS	NS
Cereals, breads, and pastries	NS	NS	NS
Salty snacks, nuts, and peanut butter	+	+	NS
Eggs and egg dishes	NS	NS	–
Fruits and vegetables	+	+	NS
Soups, beverages, and sweeteners	NS	NS	NS

disease awareness increases, the probability that a woman consumes red meats decreases, as does the relative importance of eggs and egg dishes in providing dietary fat, given that some item from this group is consumed. Conversely, higher diet-disease awareness probabilities are associated with a greater likelihood of consuming food fats, dressings, and sauces; poultry, fish, and seafood; baked and frozen deserts; salty snacks and peanut butter; and fruits and vegetables. Many of these findings are consistent with the notion that recent trends in aggregate per capita consumption (particularly the shift from red meats to poultry, fish, and seafood, and the increase in fruit and vegetable consumption) are at least partially due to increased consumer awareness of the links between diet and health (Levy and Heimbach, 1989; National Research Council, 1989 and 1991; Putnam and Allshouse, 1991).

It appears that informing the public about the link between fat consumption and chronic disease has motivated consumers to alter their dietary behavior. Most of these changes seem to involve primarily the choice of whether to consume items from particular food groups on a given day. However, it remains to be seen whether the food choices made by women most likely to be aware of the link between fat consumption and chronic disease result in lower levels of fat, saturated fat, and cholesterol intake compared with women less likely to be aware of this link.

Diet-Disease Awareness and total Intake of Fats and Cholesterol

Current dietary recommendations (National Research Council, 1991; U.S. Department of Agriculture/U.S. Department of Health and Human Services, 1990) are based on intake levels of total and saturated fat measured as a percentage of total caloric intake, and cholesterol intake measured in milligrams.[21] Consistent with these recommendations, we examine the effects of differences in diet-disease awareness probabilities on: (1) the percentage of calories a woman obtains from all fats; (2) whether a woman has a total fat intake level no more than 30 percent of total caloric intake; (3) the percentage of calories a woman obtains from saturated fat; and (4) the milligrams of dietary cholesterol a woman consumes. Two related but different measures of total fat intake are used because of the possibility that, although the average level of fat intake is approximately the same for different groups of women, one group may have a greater variance in total fat intake levels so that a higher percentage of women in that group are within the dietary guidelines.

Differences in the Consumption of Fats and Cholesterol Across Awareness Probabilities

Figures 8-11 show how the four total intake measures for fat, saturated fat, and cholesterol vary over quartiles of the fitted probability of diet-disease awareness. For both the average percentage of calories obtained from fat (fig. 8) and saturated fat (fig. 10), there are virtually no discernible differences across the probability of diet-disease awareness quartiles. The average level of total fat is 36-39 percent of calories across all quartiles and samples, above dietary recommendations. Similarly, the average level of saturated fat intake is 13-14 percent of calories across all quartiles and samples, above the recommendation that less than 10 percent of calories come from saturated fat.

Although there is more variability in the percentage of women with total fat intake levels that meet dietary guidelines (fig. 9), there is still no obvious relationship between this measure and the probability of diet-disease awareness.

The lack of difference in total dietary intake measures between women more and less likely to be aware of diet-disease relationships may not indicate that information efforts have been ineffective. It is possible that prior to the diffusion of information on the link between fat intake and

[21]Although the estimated awareness probabilities relate directly to fat and not cholesterol intake, individuals who are aware of one relationship typically are aware of the other. Because of this, and because fats and dietary cholesterol tend to be discussed together in media reports on dietary risk factors for coronary heart disease, we have decided to include analyses of dietary cholesterol intake.

Figure 8

Percentage of calories from fat, by awareness level

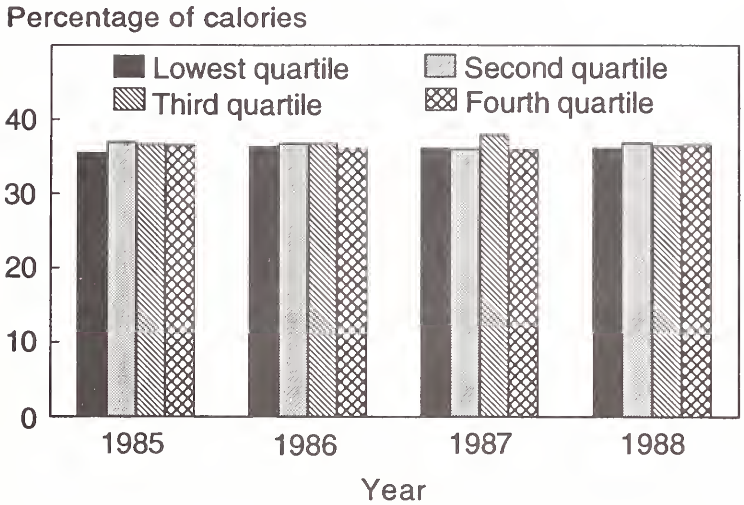


Figure 9

Proportion of women meeting dietary guidelines for fat, by awareness level

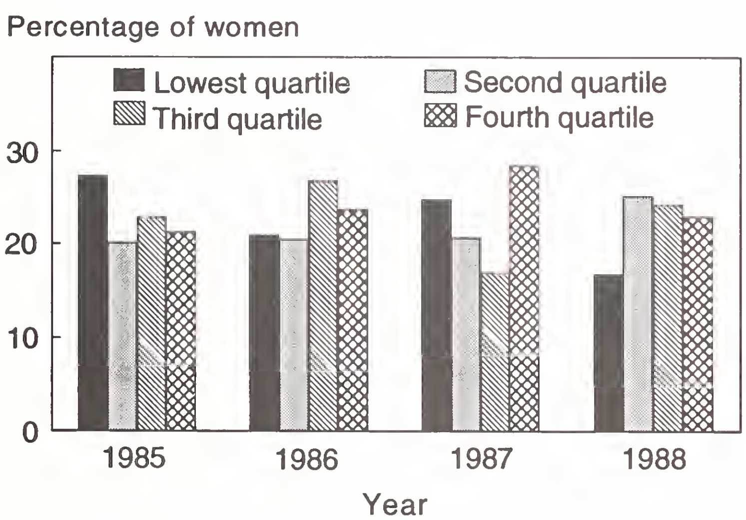


Figure 10

Percentage of calories from saturated fats, by awareness level

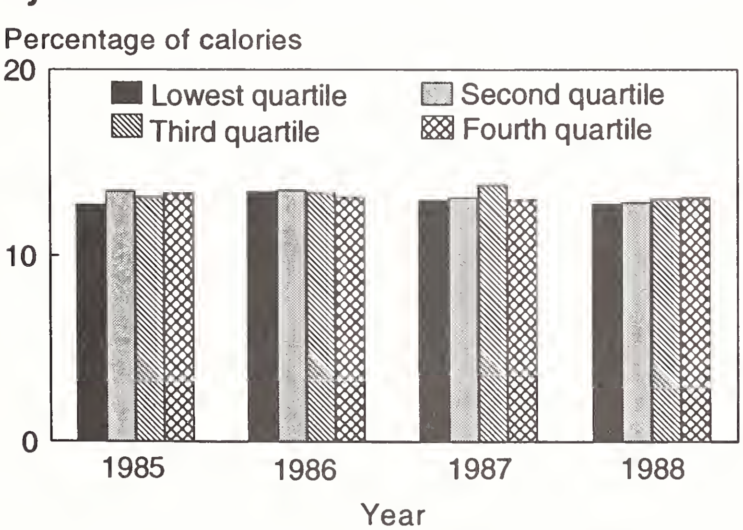
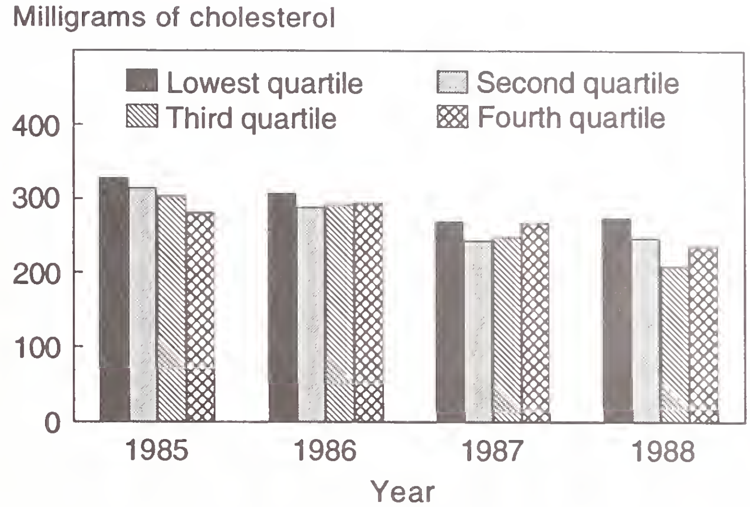


Figure 11

Average cholesterol intake, by awareness level



chronic disease, women with higher diet-disease awareness probabilities had diets higher in fat compared with women with lower probabilities of diet-disease awareness. Then, informing the public about diet-disease relationships may have been at least partially effective in prompting desired dietary changes. However, the findings of Putler and Frazao (1991) and Harris and Welsh (1989) indicate that in 1977, prior to the widespread diffusion of information on the link between fat intake and chronic disease, there were essentially no differences in total fat intake levels between women with high diet-disease awareness probabilities and women with low awareness probabilities. In other words, it appears that, as a group, women with high diet-disease awareness probabilities have, on average, been no more effective in lowering their total intake of fats and cholesterol than groups of women less likely to be aware of this information.

Multivariate Statistical Analyses of the Intake of Fats and Cholesterol

Multivariate statistical analyses of each of the four measures of total dietary intake were undertaken for two reasons: (1) to determine if the effects of the fitted diet-disease awareness probability are being confounded with other demographic factors, and (2) to assess which, if any, demographic and other characteristics are associated with differences in total intakes of fats and dietary cholesterol. The set of explanatory factors used in these analyses is the same as the set used to examine differences in food choices and dietary sources of fat (table 4).

Classical least-squares regression is used to examine the percentage of calories from both total

and saturated fat, and intake level of cholesterol, while probit analysis is used to examine the probability that a women falls within the dietary guidelines for total fat consumption. A so-called "log-odds" transformation (Pindyck and Rubinfeld, 1981) is used on the percentage of calories from both total and saturated fat.[22] This transformation of the original dependent variable results in a new dependent variable that can take on any real value, rather than values that are bounded between zero and one. As a result of this transformation, classical least-squares regression can be used rather than a limited-dependent variable estimation procedure such as the two-limit tobit. Separate equations were estimated for each measure and sample. Table 7 contains a summary of the significant estimation results.[23]

Confirming the simple analyses based on quartiles of awareness, the multivariate statistical analyses indicate that the fitted probability of awareness does not have a significant effect on any of the four measures of fat and cholesterol consumption. However, several demographic and other factors do have significant effects on total consumption of fats and cholesterol.

One factor that seems to have a relatively large effect is race and ethnicity. Both Hispanics and those in the "other" category (mostly Asians and Native Americans) have significantly lower intakes of both total and saturated fat than do non-Hispanic whites. In addition, non-Hispanic blacks have, on average, significantly higher cholesterol intake levels than non-Hispanic whites. Additional analysis reveals that non-Hispanic black women in the four samples have average diet-disease awareness probabilities considerably below non-Hispanic white women. As a result, non-Hispanic blacks comprise a large percentage of the lowest probability of awareness quartile. Consequently, the comparatively high cholesterol intake of the lowest awareness quartile in figure 11 is probably not a result of differences in diet-disease awareness, but rather of cultural differences between non-Hispanic blacks and other groups with respect to food preferences and choices.

Other factors that have a major influence on total intake of fats and cholesterol are whether a women is following a medically or self-prescribed special diet and whether the reported day of dietary intake data falls on a weekend. Women who follow a special diet have significantly lower intakes of total and saturated fat and are significantly more likely to have total fat intake levels that fall within the dietary guidelines. On average, women who reported their diets for a day that fell on a weekend have significantly higher intakes of total fat and cholesterol and are less likely to have total fat intake levels that fall within the dietary guidelines, suggesting that people have a tendency to "let go" on weekends from a dietary perspective.

Conclusion of Empirical Findings

Our analyses suggest that current efforts to inform the public about the link between fat intake and chronic disease have been effective in both making the public aware of these messages and motivating consumers to systematically alter their dietary behavior. Women with higher probabilities of diet-disease awareness are less likely to consume red meats, and consume a smaller share of fat from eggs and egg dishes. These women are also more likely to consume food fats, dressings, and sauces; poultry, fish, and seafood; baked and frozen desserts; salty snacks and peanut butter; and fruits and vegetables.

Simply increasing the likelihood that a group of women is informed of the link between fat intake and chronic disease does not result in a reduction in consumption of total fat, saturated fat, or cholesterol, despite the systematic changes in food behavior associated with diet-disease awareness. Although the data indicate that average fat intake has declined since 1977, those groups with higher diet-disease awareness showed no greater reduction in fat intake than others. In other words, the larger dietary changes made by the group of women with higher diet-disease awareness probabilities had little net effect on their total fat intake relative to other groups of women. Consumers may be having difficulties making effective food substitutions in their diets, perhaps due to insufficient knowledge about the relative fat content of different food groups.

More research is needed to understand the complex link between diet-disease awareness and actual dietary practices. With the availability of new data from HNIS's 1989-91 CSFII, which provide information on food consumption, diet-disease awareness, and specific nutrition knowledge, all for the same individual, it now becomes possible to evaluate the effect of diet-disease awareness on attitudes and specific nutrition knowledge, and, in turn, their effects on food consumption behavior.

[22] The log-odds transformation is given by $\ln[P_i/(1-P_i)]$, where P_i is the percentage of calories obtained from either total or saturated fat for woman i.

[23] A complete set of estimation results can be obtained from the authors upon request.

Table 7—Variables that significantly influence intake of total fat, saturated fat, cholesterol, and the probability of meeting the dietary guideline for fat

Variable	Percentage of calories from fat	Probability of meeting dietary guideline	Percentage of calories from saturated fat	Miligrams of cholesterol
Awareness of the female head	NS[1]	NS	NS	NS
Percentage of poveerty	NS	NS	NS	NS
Public assistance	NS	NS	NS	NS
Non-Hispanic black	NS	NS	NS	+[2]
Hispanic	–[3]	NS	–	NS
Non-Hispanic other race	–	NS	–	NS
Age	NS	NS	NS	NS
Weight	NS	NS	NS	NS
Pregnant/lactating	NS	NS	NS	+
On special diet	–	+	–	NS
Vegetarian	NS	NS	NS	NS
Male head present	NS	NS	NS	NS
Children present	NS	NS	NS	NS
Female head employed	NS	NS	NS	NS
Urban	–	NS	NS	NS
Suburban	NS	NS	NS	NS
North-Central	NS	NS	NS	NS
South	NS	NS	NS	NS
West	NS	NS	NS	NS
Weekend	+	–	NS	+

[1]NS indicates the variable did not have a significant effect.
[2]+ indicates the variable had a significant positive effect.
[3]–inidcates the variable had a significant negative effect.

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Appendix: Food Group Definitions

Red meats

Includes all separable cuts of beef, pork, lamb, veal, and game; all types of sausages, frankfurters, bacons, luncheon meats, and cold cuts; and food mixtures in which one of these meats or sausages (or a combination) represents a main ingredient (for example, hamburger on a bun, beef burritos, and pork chow mein).

Dairy products

Includes all types of fluid milk, cream and cream substitutes, yogurt (but not frozen yogurt), cheese, and food mixtures in which cheese is a main ingredient (for example, cheese pizza, meatless lasagna, and bean and cheese burrito).

Food fats, dressings, and sauces

Includes all types of oils, margarine, butter, salad dressings, and sauces.

Poultry, fish, and seafood

Includes all separable pieces of chicken, turkey, duck, goose, cornish game hen, dove, quail, pheas-

ant, fin-fish, and shellfish. The group also includes food mixtures in which these meats represent a main ingredient (for example, chicken and tuna salad sandwiches, turkey pot pie, and sweet and sour shrimp).

Baked and frozen desserts

Includes all types of cakes, cookies, cobblers, pies, puddings, ice cream, ice milk, frozen yogurt, gelatin desserts, dessert toppings, and candy.

Legumes and starches

Includes all food mixtures in which the main ingredient is a dry legume, pasta, rice, potato (except potato chips), other tubers, soyburgers, and plantains.

Cereals, breads, and pastries

Includes all cold and hot breakfast cereals, flour, breads, rolls, muffins, pastries, bagels, doughnuts, pancakes, waffles, and tortillas.

Salty snacks, nuts, and peanut butter

Includes crackers, pretzels, popcorn, chips, nuts, sunflower seeds, and peanut butter.

Eggs and egg dishes

Includes eggs, omelets, and quiches.

Fruits and vegetables

Includes all types of fresh, frozen, and canned fruits and vegetables, fruit and vegetable juices, and food mixtures where fruits or vegetables are the main ingredient.

Soups, beverages, and sweeteners

Includes sugars and sugar substitutes, honey, jams, jellies, syrups, beverages (other than fruit and vegetable juices), and soups.

The Implications of Offsetting Adjustments in Government Purchase Prices for Butter and Nonfat Dry Milk

Larry Salathe

Abstract. *Commodity Credit Corporation (CCC) purchases of milkfat have greatly exceeded CCC purchases of nonfat milk solids on a milk-equivalent basis since 1988. USDA has responded by reducing the purchase price of butter and increasing the purchase price of nonfat dry milk twice in 1990 and twice in 1992. This article examines the effects of changing the relative purchase prices of butter and nonfat dry milk on CCC dairy product purchases and dairy program costs. The results indicate that balancing CCC purchases of milkfat and nonfat solids on a milk-equivalent basis and minimizing CCC dairy product purchase costs lead to nearly the same dairy program costs.*

Keywords. *Butter, dairy program costs, milk, nonfat dry milk, price support.*

Cow's milk averages about 3.67-percent butterfat, 8.60-percent nonfat solids, and 87.73-percent water, although butterfat and nonfat solids content varies seasonally and by breed (Goold, 1982).[1] The Commodity Credit Corporation (CCC) supports the price of milk used in manufacturing by purchasing butter, cheese, and nonfat dry milk. Butter chiefly consists of milkfat, and nonfat dry milk primarily consists of nonfat solids, while the manufacture of cheese utilizes nonfat solids and milkfat in nearly the same proportions as those in cow's milk.

Butter and nonfat dry milk are joint products. This allows the CCC to reduce the butter purchase price and offset the decline with an equivalent increase in the purchase price of nonfat dry milk and not change the underlying support price for manufacturing milk. CCC's operating objective is to make offsetting adjustments in the purchase prices of butter and nonfat dry milk until purchases of milkfat and nonfat milk solids are in approximately the same proportion as their presence in cow's milk. This means that the CCC will continue to make offsetting adjustments in purchase prices until purchases of milkfat and nonfat milk solids are equal on a milk equivalent basis.[2] The U.S. Department of Agriculture (U.S. Dept. Agr., ASCS, 1991a) states that: "Achieving this goal eliminates program-caused inequities that affect the competitive situation between plants ... Also, additional farm milk and product price stability can be expected when CCC purchase prices are in alignment with market demands."

CCC purchases of nonfat solids, milk equivalent basis, averaged about 27 percent more than CCC purchases of milkfat, milk equivalent basis, during 1980-88. In contrast, CCC purchases of milkfat totaled 9.4 billion pounds milk equivalent in 1989, while purchases of nonfat solids were below 1 billion pounds milk equivalent. In response to the large imbalance in CCC purchases of milkfat and nonfat solids, USDA lowered the purchase price of butter and increased the purchase price of nonfat dry milk by an equivalent amount twice in 1990. However, CCC purchases of milkfat continued to exceed greatly purchases of nonfat solids following these two adjustments. In 1991, CCC purchases of milkfat were 2.6 times greater than purchases of nonfat solids on a milk equivalent basis, prompting USDA to reduce the purchase price of butter by 11 cents per pound and raise the CCC purchase price of nonfat dry milk by 6 cents per pound twice in early 1992.[3] These offsetting adjustments in the purchase prices of butter and nonfat dry milk, each equivalent to 50 cents per 100 pounds of milk, were similar to previous adjustments that became effective in 1990.

There may be other reasons for making offsetting adjustments in the purchase prices of butter and

Salathe is an agricultural economist with USDA's Economic Analysis Staff. The author thanks Don Blayney, John Mengel, J. Michael Price, and Mark Weimar for helpful comments.

[1]Sources are listed in the References section at the end of this article.

[2]Milk equivalents measure how much cow's milk is needed to produce 1 pound of a dairy product. Since dairy products contain different relative proportions of milkfat and nonfat solids, milk equivalents are calculated both on a milkfat and nonfat solids basis. For example, suppose that a dairy product consists of 10-percent milkfat and 10-percent nonfat solids. Thus, it would take 2.72 (10/3.67) pounds of cow's milk on a milkfat basis and 1.16 (10/8.6) pounds of cow's milk on a nonfat solids basis to produce 1 pound of the dairy product.

[3]The $1.00 per hundredweight (cwt) of milk adjustment in butter and nonfat dry milk purchase prices in 1992 also raised the cheese purchase price by $0.0075 per pound or by 0.68 percent compared with a 22.4-percent decrease in the purchase price for butter and a 14.5-percent increase in the purchase price of nonfat dry milk. Because of the small relative adjustment, this paper does not address changes in the cheese purchase price.

nonfat dry milk besides balancing CCC purchases of milkfat and nonfat milk solids for the purpose of providing product price stability. The Food, Agriculture, Conservation and Trade Act of 1990 gives the Secretary of Agriculture the authority to adjust CCC purchase prices for butter and nonfat dry milk in order to lower the cost of the dairy price support program or achieve other objectives (U.S. Congress, 1990). Thus, it would appear that Congress viewed offsetting adjustments in purchase prices as a way to reduce dairy program costs and not just as a means of stabilizing product prices.

Balancing CCC purchases of milkfat and nonfat milk solids on a milk equivalent basis may best accomplish the multiple objectives of the dairy price support program, such as stability, minimum market interference, equity between butter-powder and cheese plants, and low taxpayer cost. Setting butter and nonfat dry milk purchase prices on a basis other than equalizing CCC purchases may be inconsistent with the overall objectives of the price support program. However, it still seems reasonable to compare the relative outcomes of different rules for setting butter and nonfat dry milk prices, especially given the emphasis in current legislation on minimizing CCC costs.

This article examines the implications for dairy program costs, CCC purchases of butter and nonfat dry milk, prices of butter and nonfat dry milk, and butter and nonfat dry milk consumption of two decision rules for setting butter and nonfat dry milk CCC purchase prices. The first decision rule is to balance CCC purchases of milkfat and nonfat milk solids on a milk equivalent basis and the second is to minimize the cost of the dairy price support program. The article begins by deriving mathematically the offsetting adjustments in the purchase prices of butter and nonfat dry milk implied by each decision rule. Next, equations are developed for changes in demand for milkfat and nonfat solids that account for offsetting adjustments in butter and nonfat dry milk purchase prices. Last, butter and nonfat dry milk purchase prices, butter and nonfat dry milk purchases, and CCC outlays for the dairy program are calculated for each decision rule and compared to actual values for 1991.

The mathematical model does not consider changes in milk production, milk prices, and production of dairy products. While offsetting adjustments do not change the underlying support price for manufacturing milk, returns of butter/powder manufacturing plants could be affected if market prices for butter or nonfat dry milk greatly exceed their CCC purchase prices. A change in returns of butter/powder manufacturing plants would be expected to have some impact on milk prices, milk production, and production of dairy products. However, the difference in milk equivalent purchases of milkfat and nonfat solids would not be affected by changes in either the level of milk production or the level of butter/powder production. This is because total milk equivalents of both milkfat and nonfat solids available for processing or used in butter/powder production would change by the same amount. Thus, changes in milk production and production of butter/powder should not change the offsetting adjustment in purchase prices needed to balance CCC purchases of milkfat and nonfat solids.

Our model assumes that exports of dairy products would not be affected by offsetting adjustments in CCC purchase prices of butter and nonfat dry milk. It further assumes that the relative proportions of milkfat and nonfat solids used to produce individual dairy products do not change. These assumptions become more questionable when large adjustments in prices are projected.

Balancing CCC Purchases

If the decision rule is to balance CCC purchases, offsetting adjustments in the purchase prices of butter and nonfat dry milk will occur until CCC purchases of milkfat and nonfat milk solids are equal on a milk equivalent basis. An offsetting change in CCC purchase prices of butter and nonfat dry milk is given by:

$$\Delta P_B = -8.13\Delta P_{NF}/4.48, \tag{1}$$

where ΔP_B denotes the change in the purchase price of butter, and ΔP_{NF} is the change in the purchase price of nonfat dry milk. The coefficients in equation 1 represent the number of pounds of butter (4.48) and nonfat dry milk (8.13) obtainable from 100 pounds of milk that is used to establish the purchase prices of butter and nonfat dry milk (U.S. Dept. Agr., ASCS, 1991c).

Milk equivalent purchases on a milkfat and nonfat milk solids basis can be expressed as:

$$ME_B = 21.8AC_B, \tag{2}$$

$$ME_{NF} = 11.64AC_{NF}, \tag{3}$$

where ME_B is the milk equivalent on a milkfat basis, ME_{NF} is the milk equivalent on a nonfat solids basis, AC_B is butter purchases, and AC_{NF} is nonfat dry milk purchases (U.S. Dept. Agr., ASCS, 1991b). The milk equivalent of milkfat and nonfat milk solids purchases are affected by cheese

purchases. In addition, nonfat dry milk contains a small amount of milkfat, and butter contains a small amount of nonfat milk solids. Nevertheless, equations 2 and 3 closely approximate the change in milk equivalent purchases on a milkfat and nonfat milk solids basis, since the milk equivalent factors used for cheese closely reflect whole milk and butter and nonfat dry milk contain only very small (1 percent or less) amounts of nonfat milk solids and milkfat, respectively. These equations indicate that it takes, on average, 21.8 pounds of milk to obtain 1 pound of butter and 11.64 pounds of milk to obtain 1 pound of nonfat dry milk.

CCC purchases of butter and nonfat dry milk, after an offsetting adjustment in the CCC purchase prices of butter and nonfat dry milk, can be expressed in terms of changes in milkfat and nonfat solids consumption and the initial purchases of butter and nonfat milk solids. These equations are as follows:

$$AC_B = \underline{AC}_B - \Delta D_B/.8, \tag{4}$$

$$AC_{NF} = \underline{AC}_{NF} - \Delta D_{NF}/1.0, \tag{5}$$

where $\underline{AC}_B$ represents the initial purchases of butter, $\underline{AC}_{NF}$ represents the initial purchases of nonfat dry milk, ΔD_B is the change in the quantity demanded of milkfat, and ΔD_{NF} is the change in the quantity demanded of nonfat solids. The changes in the quantities demanded of milkfat and nonfat solids are divided by factors that convert milkfat and nonfat milk solids into butter and nonfat dry milk, respectively.

We express the demand for milkfat as a function of the purchase price of butter and the demand for nonfat solids as a function of the purchase price of nonfat dry milk:

$$D_B = BP_B^{-\beta}, \tag{6}$$

$$D_{NF} = AP_{NF}^{-\alpha}, \tag{7}$$

where α and β are the elasticities of demand for nonfat milk solids and milkfat, respectively. We link these two demand functions to changes in CCC purchases by using the following identities:

$$\Delta D_B = D_B - \underline{D}_B, \tag{8}$$

$$\Delta D_{NF} = D_{NF} - \underline{D}_{NF}, \tag{9}$$

$$\Delta P_B = P_B - \underline{P}_B, \tag{10}$$

$$\Delta P_{NF} = P_{NF} - \underline{P}_{NF}, \tag{11}$$

where $\underline{D}_B$ and $\underline{D}_{NF}$ are the initial quantities of milkfat and nonfat solids consumed, respectively, and $\underline{P}_B$ and $\underline{P}_{NF}$ are the initial purchase prices of milkfat and nonfat solids, respectively. Underlined variables are exogenous or predetermined.

To derive the purchase prices of butter and nonfat dry milk that balance CCC purchases, we set equations 2 and 3 equal to one another and solve the above system of equations. Solving this system of equations for P_{NF} yields the following equation:

$$\begin{aligned}11.64\underline{AC}_{NF} + 11.64\underline{D}_{NF} - 21.8\underline{AC}_B & \\ - (21.8/.8)\underline{D}_B &= 11.64AP_{NF}^{-\alpha} \\ &- (21.8/.8)B(-8.13\ (P_{NF} \\ &- \underline{P}_{NF})/4.48 + \underline{P}_B)^{-\beta},\end{aligned} \tag{12}$$

which expresses the price of nonfat dry milk that balances CCC purchases of milkfat and nonfat solids as a nonlinear function of the initial purchases of butter and nonfat dry milk, the initial consumption of milkfat and nonfat solids, the initial prices of nonfat dry milk and butter, and the elasticities of demand for milkfat and nonfat milk solids. Once equation 12 is solved, equations 1 and 11 can be used to solve for the price of butter that balances CCC purchases.

Minimizing CCC Outlays

An alternative decision rule would be to make offsetting adjustments in the CCC purchase prices of butter and nonfat dry milk in order to minimize CCC dairy product purchase costs. The cost minimization problem can be written as follows:

$$\begin{aligned}\text{MIN } C = {} & P_{NF}(\underline{AC}_{NF} - \Delta D_{NF}) \\ & + P_B\ (\underline{AC}_B - \Delta D_B/.8),\end{aligned} \tag{13}$$

where all terms have been defined earlier.[4] By substituting, we obtain:

$$\begin{aligned}\text{MIN } C = {} & P_{NF}\ (\underline{AC}_{NF} - (AP_{NF}^{-\alpha} - \underline{D}_{NF})) \\ & + (-8.13\ (P_{NF} - \underline{P}_{NF})/4.48 + \underline{P}_B) \\ & (\underline{AC}_B - (B(-8.13\ (P_{NF} - \underline{P}_{NF}) \\ & /4.48 + \underline{P}_B)^{-\beta} + \underline{D}_B)/.8).\end{aligned} \tag{14}$$

To determine the purchase price of nonfat dry milk that minimizes CCC dairy product purchase costs, we differentiate equation 14 with respect to P_{NF}, which leads to the following equation:

[4]The minimization problem ignores the cost of storage and potential receipts that might be realized from commercial sales of CCC-held stocks of butter and nonfat dry milk in future years. In most years, CCC storage costs and commercial sales of CCC-held stocks are relatively small compared with total dairy program costs.

$$dC/dP_{NF} = \underline{AC}_{NF} - A(-\alpha+1)P_{NF}^{-\alpha} + \underline{D}_{NF} - 8.13\underline{AC}_{B}/4.48 - 8.13\underline{D}_{B}/(.8*4.48) + [8.13(-\beta+1)B/(4.48*.8)]\,[-8.13\,(P_{NF} - \underline{P}_{NF})/4.48 + \underline{P}_{B}]^{-\beta}. \quad (15)$$

Setting equation 15 equal to zero and solving this equation for P_{NF} yields the price of nonfat dry milk that minimizes CCC purchase costs. After a solution to equation 15 is found, equations 1 and 11 an be used to solve for the purchase price of butter that minimizes CCC purchase costs.

Multiplying equation 15 by 11.64 and then comparing it with equation 12 reveals that the coefficients of $\underline{AC}_B$ and $\underline{D}_B$ are not identical in the two equations. This is because the technical coefficients for converting CCC purchases of butter and nonfat dry milk into milk equivalents do not correspond exactly to the technical coefficients used to compute equivalent changes in CCC purchase prices. This can be seen by taking the ratio of the technical coefficients in equations 2 and 3 (21.8 and 11.64) and comparing it with the ratio of the coefficients in equation 1 (8.13 and 4.48).

If we assume the ratio of the technical coefficients for determining milk equivalent purchases of butter and nonfat dry milk equals that used for determining an offsetting change in purchase prices, equations 12 and 15 are identical if α and β equal zero. This result indicates that as the demand elasticities for nonfat solids and milkfat move closer to zero the offsetting change in purchase prices of butter and nonfat dry milk needed to balance purchases moves closer to the offsetting change in purchase prices that minimizes CCC purchase costs.

Demand Responses for Milkfat and Nonfat Milk Solids

The above equations for the purchase prices of butter and nonfat dry milk depend on the elasticities of demand for milkfat and nonfat solids under offsetting purchase price adjustments. We could compute these elasticities as simple weighted averages of the elasticities of demand for individual dairy products. However, since offsetting adjustments in butter and nonfat dry milk purchase prices moves the prices of milkfat and nonfat solids in opposite directions and most dairy products contain both milkfat and nonfat solids, that approach would overstate the changes in demand for milkfat and nonfat milk solids caused by offsetting purchase price adjustments. For example, a higher price for nonfat solids would, by itself, raise the price of cheese and reduce cheese consumption. On the other hand, a lower price for milkfat would, by itself, reduce the price of cheese and increase cheese consumption. Taking into account the changes in the prices of both milkfat and nonfat milk solids, cheese prices and consumption may change only slightly, leading to little change in the amount of milkfat or nonfat milk solids consumed in the form of cheese.

To derive expressions for the elasticities of demand for milkfat and nonfat solids that account for offsetting purchase price adjustments, changes in the retail prices of individual dairy products are expressed as functions of changes in the purchase or wholesale prices of butter and nonfat dry milk. Butter and nonfat dry milk wholesale prices are assumed to be directly affected by changes in their respective purchase prices. This assumption may not be valid when CCC purchases are very small or nonexistent, in which case a moderate increase in the purchase price may not greatly influence wholesale prices. However, even in that case, a large increase in the purchase price may still lead to a sizable increase in the wholesale price. These equations are as follows:

$$dP_i = \underline{W}_{NF,i}dP_{NF} + \underline{W}_{B,i}dP_B/.8 \quad i = 1, \ldots, n, \quad (16)$$

where $\underline{W}_{NF,i} = \underline{D}_{NF,i}/\underline{D}_i$, $\underline{W}_{B,i} = \underline{D}_{B,i}/\underline{D}_i$, $\underline{D}_{NF,i}$ is the quantity of nonfat solids in the ith dairy product, $\underline{D}_{B,i}$ is the quantity of milkfat in the ith dairy product, $\underline{D}_i$ is total commercial use of the ith dairy product, and dP_i is the change the retail price of the ith dairy product. The changes in the prices of butter and nonfat dry milk are divided by factors that reflect the value of milkfat and nonfat solids in these products. Substituting equation 1 into equation 16, we obtain the following expression:

$$dP_i = \underline{W}_{NF,i}dP_{NF} - 8.13\underline{W}_{B,i}dP_{NF}/(.8*4.48), \quad (17)$$

which expresses the change in the price of the ith dairy product as a function of the change in the price of nonfat dry milk and the importance of nonfat solids and milkfat in the ith dairy product.

The total demand for nonfat solids can be expressed as a weighted summation of commercial use of individual dairy products. Taking the derivative of total demand for nonfat solids with respect to the price of nonfat dry milk, we obtain:

$$dD_{NF}/dP_{NF} = \Sigma\underline{W}_{NF,i}(dD_i/dP_i)\,(dP_i/dP_{NF}). \quad (18)$$

This equation expresses the change in consumption of nonfat milk solids caused by a change in the price of nonfat dry milk as a weighted summation of the changes in consumption of each

dairy product caused by a change in the retail price of that product multiplied by the change in the price of each product caused by the change in the price of nonfat dry milk. Substituting equation 17 into equation 18, we obtain the change in nonfat solids consumption caused by a change in the price of nonfat dry milk:

$$dD_{NF}/dP_{NF} = \Sigma \underline{W}_{NF,i}(dD_i/dP_i)(\underline{W}_{NF,i} - 8.13\underline{W}_{B,i}/(.8*4.48)). \qquad (19)$$

Further simplification and manipulation of equation 19 leads to the following expression for the elasticity of demand for nonfat solids under offsetting adjustments in purchase prices:

$$\epsilon_{NF} = \Sigma \epsilon_i \underline{P}_{NF} \underline{S}_{NF,i}(\underline{W}_{NF,i} - 8.13\underline{W}_{B,i}/(.8*4.48))/\underline{P}_i, \qquad (20)$$

where $\underline{S}_{NF,i} = \underline{D}_{NF,i}/\underline{D}_{NF}$. The latter identity denotes the share of total nonfat solids consumption accounted for by each individual dairy product. Following the same procedure, it can be shown that the elasticity of demand for milkfat under offsetting adjustments in purchase prices is as follows:

$$\epsilon_B = \Sigma \epsilon_i \underline{P}_B \underline{S}_{B,i} (-4.48\underline{W}_{NF,i}/8.13 + \underline{W}_{B,i}/.8)/\underline{P}_i, \qquad (21)$$

where $\underline{S}_{B,i} = \underline{D}_{B,i}/\underline{D}_B$. These expressions for the elasticities are functions of the initial purchase prices of butter and nonfat dry milk, the retail prices of individual dairy products, the retail demand elasticities of individual dairy products, the relative share of total milkfat and total nonfat solids consumption accounted for by each dairy product, and the proportions of nonfat solids and milkfat in each dairy product.

We used elasticities for individual dairy products that are based on estimates from earlier studies to derive numerical values for ϵ_{NF} and ϵ_B. The chosen demand elasticity for fluid milk of –.30 is very similar to those of other studies (Brandow (1961), –0.29, George and King (1971), –0.35, and Haidacher, Blaylock, and Myers (1988), –0.26). The cheese demand elasticity of –0.40 is somewhat smaller than the George and King estimate of –0.46, but higher than the Haidacher estimate of –0.33. The butter demand elasticity of –0.55 is between the Haidacher estimate (–0.17) and the George and King estimate (–0.65) as is the demand elasticity for frozen milk products of –0.35, (–0.12 and –0.52). Past studies indicate that nonfat dry milk consumption is very responsive to changes in nonfat dry milk and fluid milk prices (Salathe, Price, and Gadson, 1982). The selected demand elasticity for nonfat dry milk of –0.75 is the highest among the dairy product categories.

The demand elasticities for milkfat and nonfat solids under offsetting adjustments in butter and nonfat dry milk purchase prices were computed using data for 1991, the demand elasticities for individual dairy products in table 1, and the equations derived earlier. In 1991, nearly three-fourths of total milkfat consumption was in the form of fluid milk and cream and cheese and 90 percent of nonfat solids consumption was in the form of those products (tables 2 and 3). Butter accounted for 15 percent of milkfat consumption in 1991 and nonfat dry milk consumption accounted for just 5 percent of nonfat solids consumption.

Substituting the base demand elasticities for dairy products in table 1 and the data in tables 2 and 3 into equations 20 and 21, we obtain –0.035 for the elasticity of demand for milkfat and –0.030 for the elasticity of demand for nonfat solids. All of the change in demand for milkfat is accounted for by butter, while fluid milk and cream accounts for about 40 percent and nonfat dry milk accounts for about 50 percent of the change in demand for nonfat milk solids with offsetting adjustments in purchase prices for butter and nonfat dry milk.

Alternative values for the retail demand elasticities for butter and nonfat dry milk were selected to provide an indication of the sensitivity of the results to changes in these values. Increasing the butter retail demand elasticity from –0.55 to –0.65 increased the elasticity of demand for milkfat from –0.035 to –0.042. Raising the nonfat dry milk retail demand elasticity from –0.75 to

Table 1—Demand elasticities for dairy products

Product	Base	Alt. 1	Alt. 2	Alt. 3
Fluid milk and cream	–.30	–.30	–.30	–.30
Butter	–.55	–.65	–.55	–.65
Cheese	–.40	–.40	–.40	–.40
Nonfat dry milk	–.75	–.75	–.85	–.85
Frozen milk products	–.35	–.35	–.35	–.35

Sources: Brandow (1961); George and King (1971); Haidacher, Blaylock, and Myers (1988); Salathe, Price, and Gadson (1982).

Table 2—Consumption and prices of dairy products, 1991

Product	Commercial use	$\underline{W}_{B,i}$	$\underline{W}_{NF,i}$	Retail price
	Mil.lbs.	—Percent—		$/lb.
Fluid milk and cream	58,400	2.6	9.0	0.30
Butter	908	80.0	1.0	2.00
Cheese	6,257	34.0	85.0	3.50
Nonfat dry milk	630	.8	100.0	2.00
Frozen milk products	5,353	12.0	10.0	1.15

Sources: U.S. Dept, of Agr., ASCS (1991b); U.S. Dept. Agr., ERS (1992b).

Table 3—Milkfat and nonfat solids consumption, by product, 1991

Product	Milkfat consumption	$\underline{S}_{B,i}$	Nonfat consumption	$\underline{S}_{NF,i}$
	Mil. lbs.	Percent	Mil.lbs.	Percent
Fluid milk and cream	1,518	30.2	5,256	44.7
Butter	726	14.5	9	.1
Cheese	2,127	42.4	5,318	45.3
Nonfat dry milk	5	.1	630	5.4
Frozen milk products	642	12.8	535	4.5
Total	5,018	100.0	11,748	100.0

Source: Data calculated using information from table 2.

–0.85 increased the elasticity of demand for nonfat solids from –0.030 to –0.032.

Traditional estimates of the demand elasticities for milkfat and nonfat milk solids measure the effect of a change in one price, either milkfat or nonfat milk solids, while holding all other variables constant. Here, we allow the prices of both nonfat milk solids and milkfat to change simultaneously and in opposite directions. As a result, consumption of milkfat and nonfat milk solids should be less responsive to changes in the prices of milkfat and nonfat milk solids than those suggested by traditional demand elasticity estimates. Hutton and Helmberger (1982), using an econometric model, estimated the elasticities of demand for milkfat and nonfat solids used in manufacturing. Their shortrun estimate of the demand elasticity for milkfat is 4-5 times larger and their estimate of the demand elasticity for nonfat milk solids is 2-3 times larger than the corresponding elasticities we derived under offsetting adjustments in the purchase prices of butter and nonfat dry milk.

Model Results

The highly nonlinear equations presented earlier were solved by a iterative search process to determine the changes in the purchase prices for butter and nonfat dry milk that would have equalized CCC purchases of milkfat and nonfat solids on a milk equivalent basis and minimized CCC purchase costs in 1991. In 1991, USDA purchased 443 million pounds of butter, 268 million pounds of nonfat dry milk, and 77 million pounds of cheese at a cost of $750 million (U.S. Dept. Agr., ERS, 1992b). Purchases on a milkfat basis equaled 10.4 billion pounds compared with purchases of 3.9 billion pounds when computed on a nonfat solids basis. CCC purchase prices for butter and nonfat dry milk were 98 cents per pound and 85 cents per pound, respectively, in 1991.

The model estimates that large offsetting changes in butter and nonfat dry milk purchase prices would have been required to equalize CCC purchases of milkfat and nonfat solids on a milk equivalent basis in 1991 (table 4). The offsetting adjustment needed to balance purchases was an estimated –63 cents per pound for butter and +35 cents per pound for nonfat dry milk. This adjustment would have lowered the butter purchase price by nearly two-thirds and increased the nonfat dry milk purchase price by two-fifths in 1991. These adjustments in purchase prices would have reduced CCC purchases of butter by about 55 percent, increased CCC purchases of nonfat dry milk by about 45 percent and reduced the cost of dairy product purchases by the CCC by about $125 million. These results vary only slightly under the alternative elasticity estimates for milkfat and nonfat solids.

Making offsetting purchase price adjustments with the objective of minimizing dairy product purchase costs would have led to a slightly higher purchase price for nonfat dry milk and a moderately lower purchase price for butter than that estimated for balancing CCC removals. Thus, minimizing CCC purchase costs would have resulted in higher net removals of nonfat dry milk and lower net removals of butter than balancing removals on a milk equivalent basis. Increasing the milkfat elasticity increased the disparity between the purchase prices that would have balanced purchases of milkfat and nonfat solids on a milk equivalent basis and those that would have minimized CCC purchase costs. However, increasing the nonfat solids elasticity tended to reduce the disparity in the purchase prices between balancing CCC removals and minimizing CCC purchase costs.

In all instances, the estimates of CCC dairy product purchase costs are nearly identical whether the objective is to minimize purchase costs or balance CCC purchases. Despite significant differences in purchase prices, CCC purchase costs differ by at most $3 million between minimizing CCC purchase costs and balancing CCC purchases on a milk equivalent basis. This

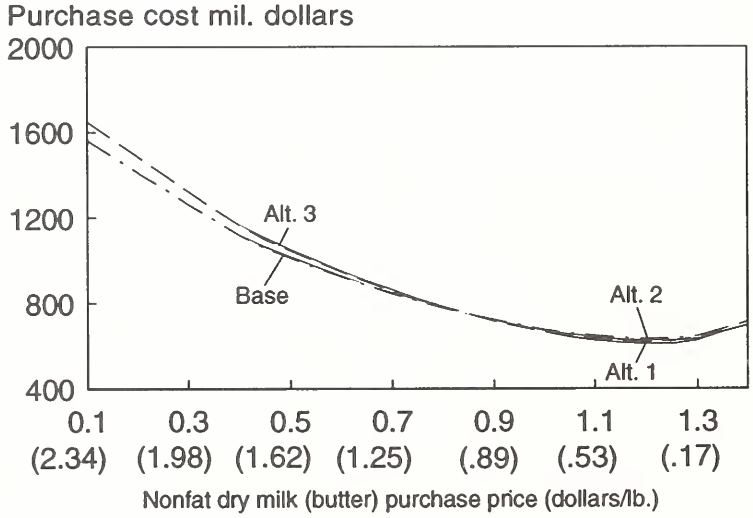
Table 4—Effects of alternative rules for setting purchase prices

Item	Units	1991 Data	Retail demand elasticities			
			Base	Alt. 1	Alt. 2	Alt. 3
			Equalizing CCC purchases			
Butter purchase price	Dollars/lb.	.98	.35	.40	.35	.41
Nonfat dry milk purchase price	Dollars/lb.	.85	1.20	1.17	1.20	1.17
Butter purchases	Mil. lb.	443	208	203	212	207
Nonfat dry milk purchases	Mil. lb.	268	389	380	397	387
CCC purchases milkfat	Bil. lb.	10.4	5.3	5.2	5.4	5.2
CCC purchases nonfat	Bil. lb.	3.9	5.3	5.2	5.4	5.2
CCC purchase cost	Mil. dol.	750	627	613	636	622
			Minimizing CCC outlays			
Butter purchase price	Dollars/lb.	.98	.30	.31	.33	.33
Nonfat dry milk purchase price	Dollars/lb.	.85	1.22	1.22	1.21	1.21
Butter purchases	Mil. lb.	443	180	132	197	150
Nonfat dry milk purchases	Mil. lb.	268	396	395	400	400
CCC purchases milkfat	Bil. lb.	10.4	4.7	3.6	5.0	4.0
CCC purchases nonfat	Bil. lb.	3.9	5.4	5.3	5.4	5.4
CCC purchase cost	Mil. dol.	750	626	610	636	620
Milkfat elasticity			-.035	-.042	-.035	-.042
Nonfat solids elasticity			-.030	-.030	-.032	-.032

suggests that there may be a considerable range of purchase prices that would lead to nearly the same cost as minimizing CCC purchase costs.

We selected various purchase prices and used equations 1-11 to examine more closely the relationship between purchase prices, CCC dairy product purchase costs, and milk equivalent purchases. CCC purchase costs fall rapidly under offsetting adjustments in purchase prices as the purchase price of nonfat dry milk increases from about 10 cents per pound to about 90 cents per pound (fig. 1). Over this range of purchase prices, CCC purchase costs decline from \$1.7 billion to \$700 million. The ratio of milk equivalent purchases of milkfat to milk equivalent purchases of nonfat solids declines from over 20 to slightly over 2 pounds of milkfat per pound of nonfat solids (fig. 2).

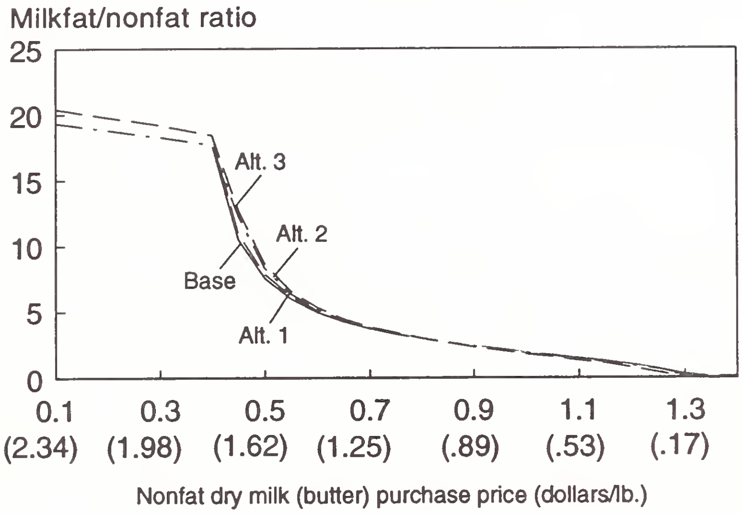
Figure 1
CCC dairy purchase costs under alternative purchase prices



In contrast, CCC purchase costs remain near \$650 million when the nonfat dry milk purchase price (and butter purchase price adjusted accordingly) is in the range of \$1.05 to \$1.30 per pound. When the purchase price of nonfat dry milk is in the range of \$1.05 to \$1.30 per pound, the ratio of milk equivalent purchases of milkfat to milk equivalent purchases of nonfat solids ranges from 1.73 to 0.13 pounds of milkfat per pound of nonfat solids. These results indicate that CCC purchase costs are fairly stable over a fairly wide range of purchase prices and over a fairly wide range in milk equivalent purchases of milkfat and nonfat solids. And, there is a considerable range in purchase prices that yield nearly the same CCC purchase costs as minimizing CCC purchase costs.

The analysis may overstate the butter price decline needed to balance purchases. The analysis assumes commercial export sales of butter do not increase as market prices decline. If U.S. export sales of butter are fairly responsive to changes in U.S. prices, the U.S. purchase price for butter may not have to fall much below the international price to balance CCC purchases. Currently, butter sells for about 60 cents per pound in international markets or quite a bit above the price at which the model estimates the butter purchase price must

Figure 2
Ratio of milk equivalent purchases of milkfat to nonfat solids



fall to in order to equalize CCC purchases of milkfat and nonfat solids (U.S. Dept. Agr., ERS, 1992a).

The analysis also assumes no new uses for milkfat. However, a large decline in the price of milkfat could result in new uses of milkfat or expanded use of milkfat in existing dairy products. New uses of milkfat or expanded use of milkfat in dairy products brought on by lower prices could also reduce the drop in the purchase price of butter needed to balance CCC purchases.

Summary

In recent years, CCC purchases of dairy products measured on a milkfat basis have greatly exceeded purchases measured on a nonfat solids basis. As a result, some product prices have been volatile. To help restore stability to product markets, USDA has responded by reducing the CCC purchase price of butter and raising the CCC purchase price of nonfat dry milk. USDA's current operating objective is to continue reducing the purchase price of butter and raising the purchase price of nonfat dry milk until CCC purchases of milkfat and nonfat solids are equal on a milk equivalent basis. Current legislation states that USDA may adjust CCC purchase prices of butter and nonfat dry milk in order to reduce CCC costs or for other reasons. This article derives mathematically the offsetting adjustment in purchase prices that would balance CCC removals of milkfat and nonfat solids on a milk equivalent basis and the offsetting adjustment that would minimize CCC purchase costs. This model is used to estimate the offsetting adjustments that would been required to balance CCC purchases and to minimize CCC dairy product purchase costs in 1991.

The results indicate that the demand for nonfat milk solids and milkfat are very inelastic under offsetting adjustments in CCC purchase prices. This is because the bulk of milkfat and nonfat milk solids are consumed in products that contain both milkfat and nonfat milk solids. With the exception of butter and nonfat dry milk, offsetting adjustments in the purchase prices of nonfat solids and milkfat cause little change in the retail prices of dairy products. The price elasticity of demand for milkfat and nonfat solids under offsetting adjustments in CCC purchase prices is estimated to be below −0.05 for both milkfat and nonfat solids.

Given the large imbalance in CCC purchases of milkfat and nonfat milk solids in 1991, the CCC purchase price of butter would have had to fall to 35-40 cents per pound before purchases of milkfat and nonfat solids would have been equal on a milk equivalent basis. The lower CCC purchase price of butter would have increased butter consumption, cutting CCC butter purchases by about 55 percent. The offsetting increase in the purchase price of nonfat dry milk would have lowered consumption of nonfat solids and increased CCC purchases of nonfat dry milk by about 45 percent. These changes in CCC purchases would have reduced CCC dairy product purchase costs by about $125 million in 1991.

Equalizing CCC purchases and minimizing CCC dairy product purchase costs would have led to similar CCC purchase prices and nearly identical dairy program purchase costs in 1991. Thus, adjusting purchase prices with the operating objective of balancing CCC purchase costs appears consistent with the objective of lowering the cost of the dairy program.

Dairy program costs were found to be fairly stable over a wide range of purchase prices for butter and nonfat dry milk. As long as the purchase price of nonfat dry milk (with appropriate adjustment in the purchase price of butter) fell in the range of $1.05-$1.30 per pound, CCC dairy product purchase costs were near those estimated to minimize CCC purchase costs. Over this range in purchase prices, the ratio of milk equivalent purchases of milkfat to nonfat solids varied from 1.73 to 0.13 pounds of milkfat per pound of nonfat solids. Thus, there appears to be a considerable range in purchase prices and milk equivalent purchases of milkfat and nonfat solids that yield nearly the same CCC purchase costs as minimizing CCC purchase costs.

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Cost, Supply, and Farm Structure: A Pedagogical Note

Lloyd D. Teigen

Abstract. *Starting with an individual firm and its quadratic production function, this paper derives all related functions: marginal and average cost, supply, profit, and input demand. Since derivatives in other functions correspond to parameters of the quadratic, the results generalize. Explicit aggregation from firm to market shows that properly specified aggregate functions depend on firm numbers. To illustrate the results, marginal and average cost functions for several dairy farms are drawn to scale, noting that large farms get more output per cow than small farms. Juxtaposing the cost curves with trends in dairy farms by size shows the link between firm-level profit and structural change.*

Keywords. *Dairy farms, production, cost, duality, aggregation, technical change, structural change, quadratic forms.*

The relationship between cost and supply curves is well-known among economists, but not always well illustrated. Consequently, perceptions of the relationship may be distorted. This note is offered in the spirit of Jacob Viner's (1931) instructions to his draftsman.

My basic criticism[1] is that textbook cost curves for the "representative" firms are drawn too close together. The impression conveyed is that alternative technologies are differentiably close to one another. Within any industry, or subsector of agriculture, there coexist firms that employ widely different technologies. For example, the technology on farms with 500 milk cows is very different from the technology on farms with 5 or 50 cows. The large farm is not a small farm that "grow'd up." Rather, it discarded the old technology and put on the new. Not many 500-cow dairies have a 50-cow barn alongside a 450-cow facility.

The curves are not always drawn to scale, and only infrequently are they related to a particular mathematical function. Beattie and Taylor's (1985) text is an exception to this generalization. Without a cardinal sense of distance, distortions can arise. With a sense of distance in the graph, relationships among firms of different size can be better visualized. Relations between supply elasticity and cost surve location (and the implied envelopes) become evident.

To illustrate the relationships with a concrete example, consider the circumstances in the U.S. dairy sector (fig. 1). The marginal and average variable cost curves for three sizes of farms are plotted in the top panel. The lower panels illustrate the trends in the number of dairy farms by size. Small farms have decreased in number exponentially. Large farms have increased in number over the last half century. The cost curves help to understand the trends in farm numbers. For any given milk price, the profit on the large farm substantially exceeds that on smaller farms. On the graph, profit is the area of a rectangle formed by the quantity at which marginal cost equals the price and the difference between marginal and average cost at that point. The rectangle formed from MC1 and AC1 is clearly smaller than the rectangle formed from MC3 and AC3. As prices change, the effect on per-firm profits can easily be mapped out.

Where did those cost curves come from? They are somewhat hypothetical, but not altogether arbitrary. The curves are those implied by a quadratic production function. They are each parametrized by a supply elasticity and a point on the marginal cost (supply) curve. In each case, the functions were evaluated where the marginal cost (price) is \$12 per hundredweight (cwt) of milk. The quantity and elasticity pairs are 50 cows and an elasticity of 0.45 in case 1, 200 cows and an elasticity of 0.3 in case 2, and 500 cows and an elasticity of 0.15 in case 3. More specifically, the quantity dimension is the "cow equivalent" unit of milk production—about 150 cwt per cow. The quantities chosen represent class boundaries in the size distribution of farms. All the small farms have cost curves to the left of MC1 (unless their price response is extremely elastic). Most of the large farms have marginal cost curves between MC1 and MC3. The overhead (or fixed) costs of the farm are not recognized in figure 1. Matulich (1978) estimated that construction, equipment, labor, insurance, and tax costs on large (375-1200 cow) dairy farms were asymptotic to about \$150 per cow in 1978, about \$1 per cwt of milk.

What is the mathematical source of those curves? The quadratic production function is the basis of

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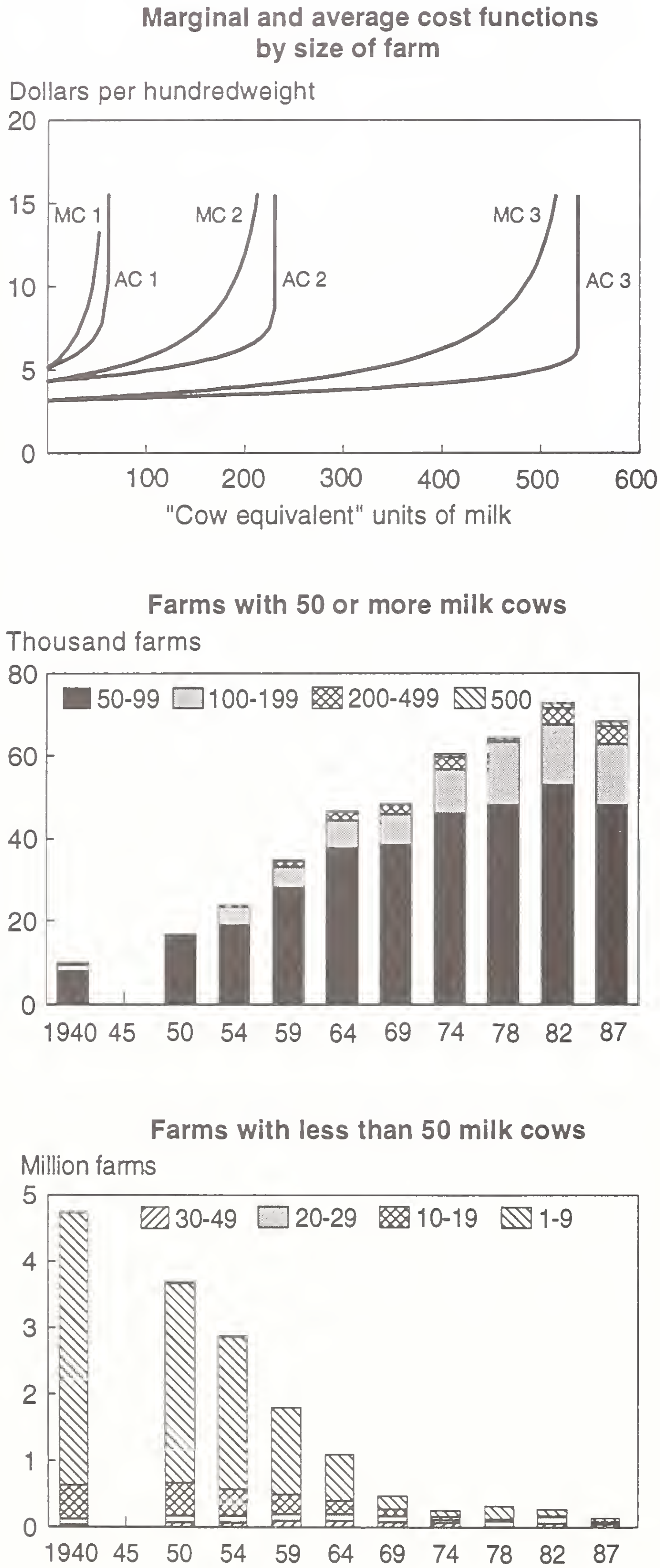
[1]This note originated as a commentary on "The Conceptual Model of Agricultural Development" in Cochrane's history of American agriculture.

Figure 1
Cost and structural change in the dairy industry



their derivation. When a firm has a quadratic production function, its supply function under profit-maximizing assumptions is a quadratic form in relative prices. This quadratic supply function is given by:

$$Y = S(w/p) = a + .5\ w'Hw/p^2. \tag{1}$$

There is a corresponding input demand function that is a linear form in relative prices, given by:

$$X = D(w/p) = b + H(w/p). \tag{2}$$

The quadratic production function is given by:

$$Y = F(X) = c + d'X + .5\ X'H^{-1}X. \tag{3}$$

In these equations, a, c, Y, and p are scalars; and b, d, X, and w are (column-) vectors; and H is a (nonsingular) negative definite, symmetric matrix. The quantity of output and the quantity of inputs are represented by Y and X. The price of output and the price of inputs are represented by p and w. The parameters a and b are related to the parameters c and d by the following:

$$a = c - .5\ d'Hd \text{ and} \tag{4}$$

$$b = -Hd. \tag{5}$$

The asymptote of the supply function is a, which measures production capacity. It is the maximum attainable output, namely that which occurs when input use equals b, the intercept of the input demand function. The optimal level of profit attainable by this firm is given by:

$$\pi = \pi^*(p, w/p) = p[\ a - b(w/p) - .5\ w'Hw/p^2\ ]. \tag{6}$$

The firm's supply function can be parametrized by assuming a price elasticity (with respect to product price) at a particular price and quantity point—treating all input prices as fixed in the analysis. Setting the point elasticity to e, and the price/quantity point as (p_o, Q_o), the parameters of the supply function are given by:

$$a = Q_o(1 + e/2) \text{ and} \tag{7}$$

$$w'Hw = -Q_o\ p_o^2\ e. \tag{8}$$

The supply function intersects the price (cost) axis at the value MC_o, equal to the marginal cost of the first unit of output, which is given by:

$$MC_o = p_o \sqrt{[e/(2+e)]}. \tag{9}$$

The marginal cost at any output, Q, for a given input price vector w, is the inverse of the supply function, given by:

$$MC(Q, w) = \sqrt{[.5(w'Hw)/(Q-a)]}, \text{ for } Q < a. \tag{10}$$

The integral of the marginal cost is the total variable cost, given by:

$$TVC(Q, w) = [\sqrt{a} - \sqrt{(a-Q)}]\sqrt{(-2w'Hw)},$$

$$\text{for } Q < a. \tag{11}$$

The average variable cost is the ratio of total variable cost to level of output, given by:

$$AVC(Q, w) = Q^{-1}[\sqrt{a} - \sqrt{(a-Q)}]\sqrt{(-2w'Hw)},$$

$$\text{for } Q < a. \tag{12}$$

The maximum average variable cost occurs as Q approaches a, and is equal to twice the marginal cost of the first unit of output, namely:

$$\lim_{Q->a}AVC(Q, w) = \sqrt{[(-2w'Hw)/a]}$$

$$= 2\ p_o\sqrt{[e/(2+e)]} = 2\ MC_o. \tag{13}$$

What if the firm doesn't have a quadratic production function? If the production function is not quadratic, but has continuous derivatives of second order, the function can be locally approximately by a quadratic function. The approximation error is the Taylor series remainder term, and approaches zero as we approach the point of approximation. Moreover, the derivatives of the true function are analogous to the parameters of the quadratic function. Thus, whatever the true production function, its derivatives should enter the firm's supply, input demand, and profit function in a manner analogous to equations 1, 2, and 6.

Does the quadratic function exhibit constant returns to scale? Not globally. But product exhaustion, in the sense of Euler's theorem, is possible. With the right combination of parameters, there is a set of inputs that exhausts total revenue when they are paid their marginal products. Namely, when c is positive, product exhaustion occurs for any $X \in \{X \in R^n : 2c + X'H^{-1}X = 0\}$. This set defines an n-dimension ellipsoid. If c is negative, the set is empty. Equation 6 determines the set of relative prices at which the product-exhausting X's would be chosen. Imposing constant returns to scale globally results in singularity of the H^{-1} matrix; consequently H would not exist under those circumstances.

How do these firm-level functions relate to the market aggregates? Market supply and profit is the sum of the supply or profit originating on each of the firms in the industry. Similarly, input use is the sum of the input demand functions across firms. It is important to distinguish between the sum of the functions (which itself is a function) and the sum of the values taken by the functions (which is a number). To indicate the summation, the subscript i denotes the individual and the subscript k denotes the distinct technologies in the industry. Further, suppose the n_k individuals use the k-th technology. Finally, assume that all firms face the same relative price vector, (w/p), and see the same product price p. Then the aggregate supply function is given by:

$$\Sigma_i\ Y_i = \Sigma_i\ S_i(w/p)$$

$$= \Sigma_k\ n_k\ a_k + .5\ w'\ (\Sigma_k\ n_k\ H_k)w/p^2. \tag{1a}$$

The aggregate input demand function is given by:

$$\Sigma_i\ X_i = \Sigma_i\ D_i(w/p)$$

$$= \Sigma_k\ n_k\ b_k + \Sigma_k\ n_k\ H_k\ (w/p). \tag{2a}$$

The aggregate profit function is given by

$$\Sigma_i\ \pi_i = \Sigma_i\ \pi_i^*(p, w/p)$$

$$= p[\Sigma_k\ n_k\ a_k - (\Sigma_k\ n_k\ b_k)(w/p) -$$

$$.5\ w'(\Sigma_k\ n_k\ H_k)w/p^2]. \tag{6a}$$

The industry "marginal cost" function is the price-dependent form of the aggregate supply function.[2] This is obtained by inverting equation (1a) and solving for p, holding relative input prices constant. To do this, the function in (1a) is linearized in the neighborhood of a point, and the linear function inverted. Let w_o/p_o be the point around which the function, $\Sigma_i S_i(w/p)$, is linearized. Let $\nabla F(x)$ represent the gradient of a function F, evaluated at x. The gradient of F is the (column-) vector whose components are the respective partial derivatives of the function F. Denote the aggregate output by Q, then the industry "marginal cost" is given by:

$$MC(Q,\ p_o,\ w_o/p_o) = p$$

$$= p_o\ [1 + (\Sigma_i\ S_i(w_o/p_o) - Q)/$$

$$\{(w_o/p_o)'(\Sigma_i\ \nabla S_i(w_o/p_o))\}]. \tag{14}$$

Those troubled by the minus sign in front of the Q are reminded that the expression in curly braces ({}) is negative. ∇S contains the partial derivatives of supply with respect to input prices, which are usually negative. Concavity of S(x) ensures that $x'\nabla S(x)$ is negative. S(x) is concave because each of the H_k matrices is negative definite.

Is there an aggregate production function consistent with these relationships? Subject to a proviso,

[2]Chambers' (1988) concept of cost aggregation across firms (p. 182) employs notation (equation 5.26) that is mathematically suspect, and differs from the industry marginal cost curve presented here as equation 14.

yes. The restriction is that the d vector of parameters must not change across firms. Klein (1946, pp. 94-95) sets forth the conditions necessary for the existence of the aggregate production function. The aggregate function must relate aggregate output to aggregate input, and its marginal products must equal the relative input prices whenever the marginal products of individual firms equal relative prices. The aggregate function which satisfies these criteria is given by:

$$\begin{aligned}\Sigma_i\ Y_i &= A(\Sigma_i X_i)\\ &= \Sigma_k\ n_k\ c_k + d'(\Sigma_i X_i) + \\ &\quad .5\ (\Sigma_i X_i)'\ (\Sigma_k\ n_k\ H_k)^{-1}(\Sigma_i X_i). \qquad (3a)\end{aligned}$$

Note, however, that this aggregate function depends intrinsically on the distribution of firms and their individual parameters. Parameters of this aggregate function depend on the distribution of firms in the industry, and are not constant over time. Consequently, its estimation presents a host of problems, which most empirical work sidesteps. Only when all firms possess the same parameters is the estimation simplified, since the number of firms would then factor out of the expressions.

Measures of technical change, in the tradition of Solow, attribute to time or technology changes in the aggregate function (3a) that result from a different (or changing) distribution of firms in the industry. Solow's Nobel Prize notwithstanding, Staehle's (1942) assessment is more correct: "... concerning technological change, the difficulties are truly insurmountable. There comes into being, of course, a new cost, if not a new production function, whenever such change occurs, and no amount of assuming, or fitting of trends to residuals will really do." (p. 271). Solow anticipates this criticism, stating: "... it takes something more than the usual 'willing suspension of disbelief' to talk seriously of the aggregate production function." Although he did not cite Klein, Solow seems aware of the tenuous link between his aggregate relationship and the rational decision units in the economy.

Other economic constructs are also linked to an aggregate relationship. The exactness of index numbers is defined in relation to an aggregate function similar to that expressed in equation 3a. If such a function does not exist, or has parameters that are not stable, exact index numbers have little meaning. Any other index number is nearly as meaningful.

Returning to costs and elasticities, the more elastic a firm's response, the more unused capacity it has. That is, the difference between a and Q_o increases with the size of the firm's supply elasticity with respect to output price. In equation 7, a is the absolute production capacity, and Q_o the production level, and the difference is unused capacity. Firms with higher price elasticities have higher average cost levels, based on equations 9 and 13. Figure 1 illustrates curves where the initial point elasticities are 0.45, 0.30, and 0.15, for firms subscripted 1, 2, and 3.

Why those particular elasticities? Elasticities of onfarm response are not common in the literature. As Cochrane and Butz (1951) said, "The aggregate output function of a representative commercial, family farm, whether a single or multiple-enterprise unit, is perfectly inelastic or approximately so; but this inelastic aggregate output function shifts to the right as technological developments are adopted on farms. (p. 469)" My own econometric estimates of equations like equation 1a imply elasticities of milk supply with respect to milk price—holding input prices and farm numbers constant—that are quite small, typically near 0.15. Elasticities in the literature, which do not hold farm numbers constant, are much larger. The range of elasticities is meant to illustrate some of the possibilities. Larger elasticities would render a "cobweb model" of the milk market dynamically unstable.

The cost structure in figure 1 reflects increasing productivity on larger farms. Census of Agriculture data document the difference in productivity or efficiency between large farms and small farms. This pattern extends as far back as 1929 (table 1). Measured on a per-cow basis, milk production or sales on farms with 100 or more milk cows is about 20 percent greater than that on farms with 30-49 cows, and sales on the smallest farms (1-29 cows) about 20 percent less. In addition, many small farms produce only for onfarm consumption and have no sales at all.

The yield difference and the changing distribution of farms explain a major part of the rising productivity of the U.S. dairy sector. However, growth accountants don't currently partition the yield gains between structural change and new technology. About a third of the yield growth between 1939 and 1987 came from structural change (in the size distribution of farms and cows), while about two-thirds came from technological change (in the production possibilities on farms of a given size). If the 1987 distribution of milk cows prevailed then, the 1929 yield per cow would have been 36.9 percent higher, and the 1939 yield would have been 44.3 percent higher. The national average milk yields were 4,500 pounds in 1929;

Table 1—Sales per milk cow and relative efficiency, by size of herd.

Census year	Number of milk cows on the farm 500 +	200-499	100-199	50-99	30-49	20-29	10-19	1-9
Milk production per cow (gallons)								
1929	←	832	700	690	681	650	574	468
1939	←	842	776	738	724	681	577	448
Whole milk sales per cow (pounds)								
1939	←	6,711	6,036	5,572	5,034	4,332	2,868	847*
1949			←	6,320	5,632	5,159	3,768	1,315*
1959		←	8,259	7,443	7,480	4,730	*→	
1964	←	9,952	8,982	8,646	8,510	7,701	6,199	1,852*
Dairy product sales per cow (dollars)								
1969	←	630	590	552	511	427	349	406
1974	1,048	949	878	818	747	648	571	556
1978	1,357	1,255	1,202	1,127	1,043	892	783	828
1982	1,852	1,715	1,604	1,523	1,402	1,189	1,061	866
1987	1,849	1,713	1,688	1,577	1,488	1,225	1,109	1,080
Relative efficiency, compared with 30-49-cow farms								
Milk production per cow (gallons)								
1929		← 1.222	1.027	1.013	1.000	0.955	0.843	0.687
1939		← 1.164	1.072	1.019	1.000	.942	.798	.619
Whole milk sales per cow (pounds)								
1939		← 1.333	1.199	1.107	1.000	.861	.570	.168*
1949				← 1.122	1.000	.916	.669	.233*
1959			← 1.104	.995	1.000	.632*→		
1964		← 1.169	1.055	1.016	1.000	.905	.728	.218*
Dairy product sales per cow (dollars)								
1969		← 1.231	1.154	1.081	1.000	.836	.682	.795
1974	1.403	1.270	1.175	1.095	1.000	.867	.765	.744
1978	1.300	1.203	1.152	1.080	1.000	.854	.750	.794
1982	1.321	1.224	1.145	1.087	1.000	.849	.757	.618
1987	1.277	1.183	1.166	1.089	1.000	.846	.766	.746

← Last tabulated entry describes all larger farms.
→ Last tabulated entry describes all smaller farms.
(*) Not adjusted for farms without sales.
Source: *Census of Agriculture* various years.

4,512 pounds in 1939; and 13,819 pounds in 1987. Adjusted for the 1987 distribution of cows, the yields would have been 6,161 pounds in 1929 and 6,512 pounds in 1939. Similarly, if the 1929 distribution of cows prevailed in 1987, the national average yield would have been less—about 28-29 percent lower (between 9,832 and 9,937 pounds per cow).

The envelope representing the longrun average cost for the firms illustrated in figure 1 is the cost structure in AC3, the lowest of the three average cost curves. Ultimately, firms using technologies 1 and 2 go out of business, and all surviving firms employ technology 3 regardless of the milk price. This is the consequence of the increasing inelasticity of price response with firm size. If the price response were increasingly elastic as size increased, the cost curves would more closely resemble the textbook envelope curves. In those cases, smaller firms would have the least cost under low milk prices and larger firms would have the cost advantage under higher milk prices, in effect swapping curves 1 and 3 in figure 1. If all three firms had the same price elasticity of supply, all the curves would intersect the cost axis at the same point.

Summary

Cost curves for firms of different sizes, when drawn to scale, show clear differences in their gross and net income positions, which explain the growth and decline in numbers of farms by size. The relationship between supply in the aggregate

and supply on the farm has been made explicit. The relationship between the firm-level supply function and the firm's marginal and average variable cost is derived. The "duality" relationships among the production, marginal cost, and profit functions on the farm is illustrated. The explicit aggregation process shows how aggregate functions depend on the number and distribution of farms, as well as parameters of the firm-level response. In the U.S. dairy industry, change in the number and size of farms accounts for about one-third of the growth in per-cow milk yield between 1929 and 1987.

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Some Valuable Information, but an Uneven Presentation

Agricultural Trade: Principles and Policies. *By Luther Tweeten. Boulder, CO: Westview Press, 1992, 319 pp., $69.50/$29.85 hardback/paperback.*

Reviewed by Fred J. Ruppel

As a professor of international agricultural trade, I searched many years for a textbook that covered the material that I felt needed to be covered for my senior-level agricultural economics students. My list of the necessary material fell into five categories: (1) current issues and historical perspectives on international agricultural trade; (2) trade theory; (3) commercial policies and market interventions; (4) marketing, markets, and institutions; and (5) international macroeconomics.

The available texts were of two types, those radiating from the mother discipline of international economics and those from an agricultural economics perspective. International economics textbooks were typically too heavy on economic theory and too light on applications to policy analysis and economic decision-making. Agricultural economics texts offered too great a focus on the policy aspects of international trade or on markets and international marketing, to the exclusion of the many interrelated elements of the economics of international agricultural trade.

The contents to *Agricultural Trade: Principles and Policies* seemed to offer a reasonable alternative to the available texts. Two chapters (1, 10) covered current issues and historical perspectives on international agricultural trade. Another two chapters (2, 3) were targeted to trade theory, one from a theoretical perspective and one with an empirical orientation. Four chapters (4, 5, 9, 11) highlighted policy; three chapters (7, 8, 9) covered market structures and institutions; and one chapter (6) focused on macroeconomic policies and exchange rates. Finally, chapter 12 covered theoretical and empirical agricultural trade model building. My wish list was apparently complete—all of my topics appeared to be covered!

As I read the chapters, however, my hopes began to fade. Chapter 1 focused on the importance of international trade, offered a brief history of U.S. agricultural trade, and discussed eight new developments in world trade. Tweeten had suggested that chapter 1 (and chapters 9, 10, and 11) would be "quite readable for persons with little, if any, background in economics" (p. xiii). But, I found this introductory chapter to be quite difficult for the uninitiated, especially the international macroeconomic relationships covered within the new developments section. Although Tweeten assumes his readers are intermediate economists, even that level of expertise may not suffice.

I would have preferred chapter 2 be more background/overview on worldwide agricultural trade, such as chapter 10's "Major Players in World Trade." Instead, chapter 2 moves directly to the theory of international trade, focusing on comparative advantage and the gains from trade. This is a reasonable flow, however, in that Tweeten's historical presentation of trade theory ties in well with the historical trade background in the previous chapter. Unfortunately, chapter 2 suffers from too great a coverage of some topics that belong elsewhere and from too little pedagogy offered to the more important topics. Tweeten's policy background surfaces much too quickly in his premature coverage of trade barriers (quotas, tariffs, optimal export taxes) and the theory of the second best. In addition, topics like the Leontief Paradox, the Stolper-Samuelson and Rybczynski Theorems, and the proof of the Hecksher-Ohlin Theorem are better left to advanced international economics textbooks. Chapter 2 has too few diagrams, and the theoretical flow, especially the flip-flopping between general and partial equilibrium, is not intuitive. Too much is presented too quickly and too cryptically. A two-chapter split of international trade theory would have helped.

Chapter 3 is good, but its focus on measuring policy interventions fits more appropriately as a postlude to the next three chapters, following Tweeten's discussions of border interventions, domestic agricultural programs, and macroeconomic policy. Misplaced material includes measures of nominal and effective protection, classical welfare impacts of policy changes (including dumping), an analysis of exchange rate distortions, and a discussion of producer and consumer subsidy equivalents. Appropriate coverage includes a section on measuring comparative advantage by domestic resource cost analysis.

The next two chapters find Tweeten in his home element: agricultural policy. Chapter 4 looks at border measures—taxes (tariffs), subsidies, and quotas. The importer-exporter intervention dicho-

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tomy is presented for each type of intervention, resulting in six diagrams. The application of each of three country types (small, large, and very large) to each diagram results in 18 possible cases. The diagrams are all well-drawn and well-documented, and the discussion is clear and uncluttered. Chapter 5 covers domestic commodity policies, including price ceilings and floors, production enhancements, mandatory controls, and a variety of two-price mechanisms. The discussion is both descriptive and analytical, with a focus on the agricultural policies of larger developed countries since programs in these countries "entail the largest social costs in foregone world income" (p. 99).

International economics textbooks typically devote half of their text to international monetary theory, essentially international finance and macroeconomics. In chapter 6, Tweeten gleans only the essentials of international finance theory, presenting instead applied topical coverage that includes international payments accounting, the foreign exchange market, domestic price and quantity impacts from exchange rate changes (including empirical estimates), macroeconomic linkages, and his own earlier work on the "economic degradation process." Covered too lightly is open economy macroeconomics, that is, national income determination and impact multipliers in an international context. Research has shown worldwide economic conditions to be crucial determinants of a country's agricultural export levels (Batten and Belongia, 1984).[1]

Tweeten continues his analysis of market imperfections in the next two chapters. Chapter 7 focuses on game theory and the theory of duopoly, while Chapter 8 extends strategic trade theory to traditional economic analysis and to imperfections that offer market players some degree of market power. Strategic trade theory is relatively new ground in international economics, and Tweeten provides an excellent overview, although the algebraic orientation will be difficult for less advanced readers. In Tweeten's defense, however, this material (much of which originates in the public choice literature) is difficult even for advanced students (and instructors!). Chapter 8 focuses on imperfectly competitive markets with discussions of producer cartels, market segmentation and price discrimination, intra-industry trade, and political economy. The two chapters provide an excellent primer for seasoned economists to become familiar with the "new international economics."

Chapters 9, 10, and 11 are a largely descriptive return to the realities of international agricultural trade. Chapter 9 introduces three of the institutions that have major impacts on agricultural trade levels and directions: the International Monetary Fund, the World Bank, and the General Agreement on Tariffs and Trade (GATT). The GATT discussion leads naturally into international commodity agreements and economic integration. Chapter 10 is a discussion of the policies and practices of the major players in world trade. Tweeten focuses first on the three economic superpowers (the United States and Canada, the European Community, and Japan), then on some lesser nations, regions, and alliances that affect agricultural trade, and concludes with justifications for trade barriers. Chapter 11 presents U.S. agricultural trade policy, while chapter 12 describes theoretical and empirical attempts to model world agricultural trade.

In his Preface, Tweeten envisions three uses and target audiences for his book: (1) an information source on international agricultural trade for the general public, (2) a textbook for graduate and upper-division undergraduate students, and (3) a resource and reference book for trade and policy research. I maintain that he fails in his first objective: the "uninformed public" will not be able to digest large chunks of his book without a heavy dose of intermediate micro- and macroeconomic theory. Tweeten is clearly biased toward the benefits of free trade over protectionism, but his message is filtered through complex economic analysis. His policy background and biases permeate the text, making it similar to others already in print.

In his second objective, Tweeten is moderately successful, although undergraduates and less-learned graduate students will have difficulty with a great deal of the material. The real value of this first edition will be to the third target audience, the research community, who will find the text useful, informative, and not overly taxing. Professional economists and agricultural economists who want to add agricultural trade to their economics toolkit will be well served by this book.

[1]Batten, D. S., and M. T. Belongia. 1984. "The Recent Decline in Agricultural Exports: Is the Exchange Rate the Culprit?," *The Federal Reserve Bank of St. Louis Review*. Vol. 66, pp. 5-14.

Focus on Dairy and Demand

Market Demand for Dairy Products. *Edited by S. R. Johnson, D. Peter Stonehouse, and Zuhair Hassan. Ames: Iowa State University Press, 1992, 310 pages, $19.95.*

Reviewed by Olan D. Forker

This book contains more than the title implies. It goes well beyond demand for dairy products. It contains a wealth of information about demand analysis, including alternative theories and methods of analysis, market demand studies for various dairy products, and the impact of generic advertising on the demand for commodities.

A collection of 15 papers by 23 authors (from the United States, Canada, New Zealand, Australia, the Netherlands, and England), the book evolved from a 1985 workshop by the International Dairy Federation in Ottawa, Canada. "The theme of this workshop dealt with the applications of and experiences with econometrics and other modeling techniques for demand analysis, forecasting, and policy evaluation in the dairy industries of IDF member countries." The purpose of the book is to "provide an up-to-date information base on recent and prospective developments in the theory and empiricism of consumer demand." The editors claim that their book is intended for two groups: (1) academicians, researchers, and students, and (2) industry participants and advisers in developed and developing countries. The book is a good reference for both groups. The chapters on theory and methodology serve as useful references for graduate students and professionals doing demand analysis of any food or food system. The authors evaluate and discuss tradeoffs in using alternative demand models and estimating techniques. The discussions on consumer demand theory, data sources, and measurement issues are especially useful.

Teklu and coauthors discuss basic consumer demand theory and compare various empirical demand systems using household production theory and market demand systems. Buse presents alternative data sources that are available for demand analysis, comparing the strengths and weaknesses of each source in relation to its appropriateness for demand studies. Schrimper discusses measurement issues and points out the need to avoid erroneous inferences by thoroughly understanding the nature and source of the data being used.

The chapters that contain research results provide information about the impact of prices, advertising, and government policy on the demand for dairy products. Griffith and others describe and analyze dairy policy in five milk-producing regions—Australia, Canada, the European Community, New Zealand, and the United States. They discuss each region's intervention measures and their effects on demand for milk and milk products. Cluff and Stonehouse provide a good discussion of the unique quantitative requirements for analyzing the demand for dairy products in Canada, a supply-managed industry.

Haidacher furnishes estimates of the demand structure for dairy products in the United States. Various estimates of price, income, and demographic relationships are evaluated. Hallberg shows estimates of the demand structure on manufacturing milk in the United States.

The incorporation of advertising into demand analysis has become important as large sums of money are now invested in commodity advertising and promotion programs. Several chapters are useful to those interested in generic advertising. Chang and others conclude that it is possible to explicitly incorporate advertising effects into complete demand systems. Cox develops a general framework for including advertising in demand analysis. Critical of past research, he calls for a "more rigorous and systematic evaluation of the research rules of thumb that we inherit and maintain ... to operationalize demand theory for more than motivating consumption as a function of price and income." The reviewer strongly supports this call. Two studies, one for butter (Goddard) and one for fluid milk advertising (Goodard and others) provide examples of empirical estimation of the impact of generic advertising on demand.

This book collects a wealth of easy-to-read information about theoretical and methodological issues in demand analysis. Authors effectively use studies of dairy product demand to illuminate the structure of demand for dairy products.

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